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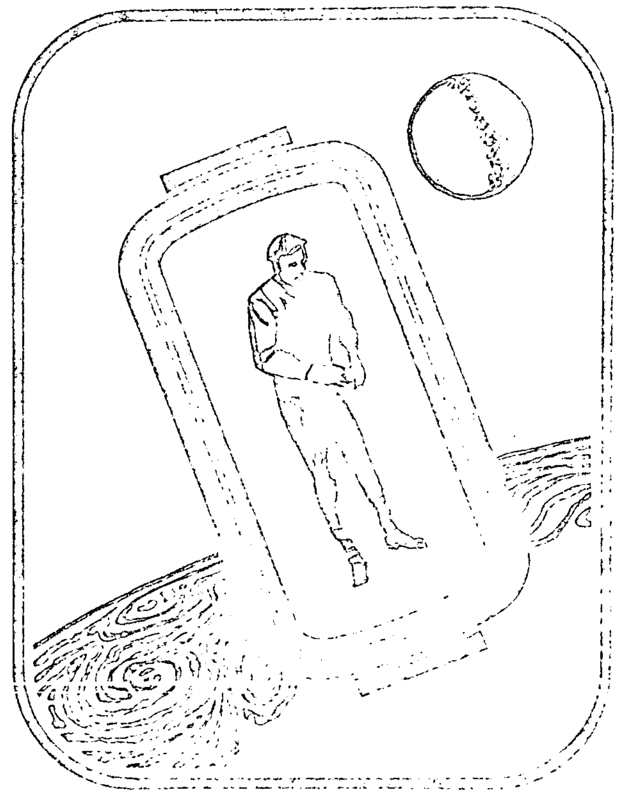
MODULAR space station

PHASE B EXTENSION

PRELIMINARY PERFORMANCE SPECIFICATION

Volume II · Project



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12214 Lakewood Boulevard, Downey, California 90241

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Approved by

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ABSTRACT

THIS VOLUME DEFINES THE INTERFACES BETWEEN THE MODULAR SPACE STATION PROGRAM ELEMENT AND THE SPACE SHUTTLE. THE DATA RELAY SATELLITE, AND THE EARTH-ORBITING EXPERIMENT PROGRAM ELEMENT WAS SYNTHESIZED FROM INTERNAL EXPERIMENTS, ATTACHED RESEARCH AND APPLICATIONS MODULES, AND DETACHED RESEARCH AND APPLICATIONS MODULES TO PROVIDE AN INTERFACE WHICH WOULD SUPPORT THE MULTIPLE COMBINATIONS OF THIS ELEMENTS EXPECTED DURING THE MISSION. THE MODULAR SPACE STATION PROGRAM ELEMENT IS COMPRISED OF THE MODULAR SPACE STATION SYSTEM (DESCRIBED IN VOLUME I), THE PREMISSION OPERATIONS SUPPORT SYSTEM, THE MISSION OPERATIONS SUPPORT SYSTEM, AND THE CARGO MODULE SYSTEM.

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FOREWORD

This document is one of a series required by Contract NAS9-9953, Exhibit C, Statement of Work for Phase B Extension-Modular Space Station Program Definition. It has been prepared by the Space Division, North American Rockwell Corporation, and is submitted to the National Aeronautics and Space Administration's Manned Spacecraft Center, Houston, Texas, in accordance with the requirements of Data Requirements List (DRL) MSC-T-575, Line Item 66.

Total documentation products of the extension period are listed in the following chart in categories that indicate their purpose and relationship to the program.

ADMINISTRATIVE REPORTS	TECHNICAL REPORTS		STUDY PROGRAMMATIC REPORTS	DOCUMENTATION FOR PHASES C AND D	
				SPECIFICATIONS	PLANNING DATA
EXTENSION PERIOD STUDY PLAN DRL-62 DRD MA-207T SD 71-201	MSS PRELIMINARY SYSTEM DESIGN DRL-68 DRD SE-371T SD 71-217	MSS DRAWINGS DRL-67 DRD SE-370T SD 71-216	EXTENSION PERIOD EXECUTIVE SUMMARY DRL-65 DRD MA-012 SD 71-214	MSS PRELIMINARY PERFORMANCE SPECIFICATIONS DRL-66 DRD SE-369T SD 71-215	MSS PROGRAM MASTER PLAN DRL-76 DRD MA-207T SD 71-225
QUARTERLY PROGRESS REPORTS DRL-64 DRD MA-208T SD 71-213, -235, -576	MSS MASS PROPERTIES DRL-69 DRD SE-372T SD 71-218, -219	MSS MOCKUP REVIEW AND EVALUATION DRL-70 DRD SE-373T SD 71-220			MSS PROGRAM COST AND SCHEDULE ESTIMATES DRL-77 DRD MA-013(REV. A) SD 71-226
FINANCIAL MANAGEMENT REPORTS DRL-63 DRD MF-004	MSS INTEGRATED GROUND OPERATIONS DRL-73 DRD SE-376T SD 71-222	MSS KSC LAUNCH SITE SUPPORT DEFINITION DRL-61 DRD AL-005T SD 71-211			MSS PROGRAM OPERATIONS PLAN DRL-74 DRD SE-377T SD 71-223
	MSS SHUTTLE INTERFACE REQUIREMENTS DRL-71 DRD SE-374T SD 71-221	INFORMATION MANAGEMENT ADVANCED DEVELOPMENT DRL-72 DRD SE-375T SD 72-11			
	MSS SAFETY ANALYSIS DRL-75 DRD SA-032T SD 71-224				

This document is Volume II, Project Level, of the Modular Space Station Preliminary Performance Specification. Volume I, Initial Station Systems (SD 71-215-1), contains the detailed requirements and characteristics of the seven functional subsystems which comprise the modular space station system.

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CONTENTS

Section		Page
1.	SCOPE	1
2.	APPLICABLE DOCUMENTS	3
3.	REQUIREMENTS	5
	3.1 PERFORMANCE	5
	3.1.1 Characteristics	5
	3.1.2 Project Definition	41
	3.1.3 Operability	43
	3.2 SYSTEM DESIGN AND CONSTRUCTION STANDARDS	45
	3.2.1 Design Compatibility	45
	3.2.2 Design Criteria	46
	3.2.3 Selection of Specification and Standards	46
	3.2.4 Material, Parts, and Processes	47
	3.2.5 Standard and Commercial Parts	47
	3.2.6 Moisture and Fungus Resistance	47
	3.2.7 Corrosion of Metal Parts	48
	3.2.8 Interchangeability and Replaceability	48
	3.2.9 Workmanship	48
	3.2.10 Electromagnetic Interference	48
	3.2.11 Storage	49
	3.2.12 Drawing Standards	49
	3.2.13 Coordinate System Standards	49
	3.2.14 Contamination	49
	3.3 SYSTEM REQUIREMENTS	51
	3.3.1 Requirements for Modular Space Station System	51
	3.3.2 Premission Operations Support Systems Requirements	64
	3.3.3 Requirements for Mission Operations Support System	68
	3.3.4 Requirements for Cargo Module System	70
4	QUALITY ASSURANCE	77
5	PREPARATION AND DELIVERY	79

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ILLUSTRATIONS

Figure		Page
3-1	Initial Space Station Buildup Sequence	9
3-2	Power Module Berthing	11
3-3	Typical Delivery Operations Sequence	13
3-4	Initial Space Station Configuration Buildup	14
3-5	Shuttle First Module Launch Capability	15
3-6	Mission Sequence Plan Summary (Typical)	18
3-7	MSS Program Element Operations	22
3-8	Shuttle Countdown Timeline	24
3-9	Cumulative Cargo Requirements	38
3-10	Specification Tree	42
3-11	Functional Block Diagram	42
3-12	Modular Space Station Configuration	52
3-13	Station Dimensional Characteristics	52
3-14	Core Module	54
3-15	Power Module	54
3-16	Station Module Features	55
3-17	Crew and Control Station Modules	56
3-18	Laboratory and ECS Station Modules	58
3-19	Station Subsystems	59
4-1	Integrated Program	78

TABLES

Table		Page
3-1	On-Orbit Propellant Requirements (First Module Delivery)	15
3-2	Shuttle Tariffs	16
3-3	Crew Skills Distribution for Initial Space Station (Typical)	20
3-4	TDRS Interface Characteristics	35
3-5	MSS to TDRS Modes	36
3-6	TDRS to MSS Modes	36
3-7	Average Cargo Requirements	38
3-8	MSP Statistical Summary	39
3-9	System Electrical Power Summary	57
3-10	Module Dry Weight Summary	59
3-11	Cargo Module Gas Storage	62

1. SCOPE

This document (Volume II of two volumes) describes the four systems of the modular space station protect and defines the interfaces between this project and the shuttle project, the tracking and data relay satellite project and an arbitrarily defined experiment project. The experiment project was synthesized from internal experiments, detached research and application modules, and attached research and application modules to derive a set of interface requirements which will support multiple combinations of these elements expected during the modular space station mission.

The modular space station project element described defines a six-man orbital program capable of growth to a 12-man orbital program capability. However, the requirements unique to the growth orbital program are not specified at this time.

The modular space station project element specification defines (1) the modular space station system, (2) the premission operations support system, (3) the mission operations support system, and (4) the cargo module system and their interfaces.

Volume I of the specification contains the detailed requirements and characteristics of the seven functional subsystems which comprise the modular space station system.

2. APPLICABLE DOCUMENTS

MIL-B-50878	Bonding, Electrical and Lightning Protection for Aerospace Systems
MIL-E-6051D	Electromagnetic Capability Requirements, Systems Amend. I
MIL-STD-461	Electromagnetic Characteristics, Requirements for Equipment
Contract NAS9-9953	Exhibit C - Statement of Work for Phase B Extension Modular Space Station Program Definition
MSC-03696	Guideline and Constraints Document, Modular Space Station Definition Phase B, Rev. 7
MSC-02466 SD 71-201	Modular Space Station Extension Period Study Plan
MSC-02469 SD 71-215-1	Modular Space Station Preliminary Performance Specification - Initial Station Systems
MSC-02471 SD 71-217	Modular Space Station Preliminary System Design (7 Volumes)
MSC-02472 SD 71-219	Modular Space Station Mass Properties - Final Report
MSC-02474 SD 71-221	Modular Space Station Shuttle Interface Requirements
MSC-02476 SD 71-222	Modular Space Station Integrated Ground Operations
MSC-02477 SD 71-223	Modular Space Station Program Operations Plan

SD 71-206	Modular Space Station Phase B Definition - Shuttle Model - (Rev. June 1971)
MSC-02479 SD 71-225	Modular Space Station Program Master Plan
NHB 7150.1	Preliminary Edition of Reference Earth Orbital Research and Applications Investigations (Blue Book) (January 1971)(8 Volumes)
NHB 8040.2	Apollo Configuration Management Manual

3. REQUIREMENTS

3.1 PERFORMANCE

3.1.1 CHARACTERISTICS

The modular space station project will provide a semipermanent cluster of modules in orbit with its associated operational support elements on the ground which is capable, in conjunction with the space shuttle project, of supporting an effective long-duration earth-orbital experiment program. In particular, it will support an on-orbit general-purpose laboratory and any combination of two attached or detached research and applications modules (RAM's).

3.1.1.1 Mission Performance

3.1.1.1.1 Guidelines and Constraints

3.1.1.1.1.1 General

The MSS program includes the design, development, and operation of a semipermanent cluster of modules, each of which can be transported to and from orbit inside the space shuttle.

The space station will be capable of use in an orbit of 55-degree inclination at an altitude between 240 and 270 nautical miles.

The initial modular space station will be operational when fully manned (at least six crewmen), and fully configured (including general-purpose laboratory capability and the capability to accommodate two research and application modules).

Commonality is a primary consideration throughout the study. As a goal, common module structures, systems and subsystems, and assemblies for space station modules, cargo modules, and research and applications modules should be developed.

Total cost of the program is a primary consideration. Primary emphasis is on minimum cost to the initial operational capability (IOC).

Safety is a prime consideration throughout the program. As a goal, no single malfunction or credible combination of malfunctions and accidents will result in serious injury to personnel or to crew abandonment of the space station.

The design-to weight of shuttle-transported modules shall not exceed 20,000 pounds.

The maximum external dimensions of the modules shall be 14 feet in diameter and 58 feet in length. Mechanisms that are external but attached to the module, such as handling rings, attachments for deployment, berthing mechanisms, storage fittings, and thrusters, shall be contained at launch within an envelope 15 feet in diameter and 60 feet in length.

A shirtsleeve environment will be provided within habitable areas for crew activities during the buildup, activation, and module replacement periods.

The space station structure and subsystems will be designed for an oxygen-nitrogen mixture at a normal operating pressure of 14.7 psia.

The initial space station shall be capable of supporting selected, partial, modified, or combined functional program elements (FPE's) from the NASA-defined experiments, NHB 7150.1 (Blue Book). Blue Book experiments and RAM's are to be scheduled in accordance with station capability. Modified FPE's will require the approval of NASA.

The allowable radiation limits for the crew are:

Organ	Limit Dose (rem)					
	Depth	Daily*	30-Day	Quarterly**	Yearly	Career
Skin	(0.1mm)	0.6	75	105	225	1200
Eye	(3.0mm)	0.3	37	52	112	600
Marrow	(5.0cm)	0.2	25	35	75	400

*One-year average

**May be allowed for two consecutive quarters with 6 months' restriction from further exposure to maintain yearly limit.

The space station will be capable of accommodating a mixed male-female crew.

3.1.1.1.1.2 Operations

The space station will rely on the shuttle for emergency removal of the crew within 48 hours of alert notification. However, 96 hours of emergency provisions will be maintained on orbit.

At least 30 days' consumables, including subsystems and experiments, will be available beyond the scheduled resupply mission.

Management of long-range overall mission planning for the station will be performed on the ground.

Shuttle launch frequency, to support the space station program, will be no greater than one every 30 days.

The initial space station shall have the capacity for independent operation with the full crew for a period of 120 days.

As a goal, no orientation restrictions will be imposed by subsystems (e.g., electrical power, thermal control, communications).

The capability to return modules to the ground for maintenance and repair will be provided.

Prelaunch and launch operations will be developed so as to require minimum access to the module while in the orbiter cargo bay.

The capability shall be provided for monitoring the space station in an unmanned condition to confirm the existence of a habitable environment and the functional capabilities of critical life-sustaining subsystems.

3.1.1.1.1.3 Configuration

The initial space station will be sized to accommodate at least six crewmen. Provision for double occupancy will be made in case it is required during relief crew overlap periods.

There is no requirement that the initial space station configuration accommodate an artificial-gravity experiment.

A minimum of two separate pressurized habitable volumes with independent life support capability and provisions and other essential services will be provided at each manned stage of cluster buildup and operation.

The space station will provide private crew quarters for the nominal crew. Other habitability provisions will be in consonance with prior Phase B studies (August 1970) to the maximum degree practical.

3.1.1.1.2 Mission Operations

3.1.1.1.2.1 Buildup Operations

Buildup of the modular space station (MSS) will require interfacing operations between the space station program elements and the space shuttle program elements. The characteristics of these interfacing operations are summarized in this section.

The initial space station buildup phase begins with the shuttle launch and delivery to orbit of the first module and is completed when the station is fully activated and manned by the initial six-man crew. The buildup sequence selected for the initial MSS consists of the seven steps summarized in Figure 3-1. Since the assembly period is constrained by the shuttle launch frequency of one every 30 days, the overall buildup time associated with the selected sequence is at least 180 days.

The initial module (core module) is delivered to orbit by the shuttle on Day 0. Upon reaching the initial operational orbit in approximately four hours, the core module is partially activated in the shuttle cargo bay. After the operational integrity of the module is verified, it is deployed from the cargo bay by the shuttle manipulator. Additional remote activation by RF link and operational verification is required before release of the core module in a gravity-gradient flight mode. Before shuttle departure, the core module is commanded to a quiescent mode of operation; this will be the nominal mode until partial activation prior to the next shuttle delivery. The core module will transmit subsystem status data once a day during the quiescent operational period.

Thirty days after launch of the core module, the power module is launched. The time from launch to rendezvous with the core module can vary from approximately four hours up to 26 hours since shuttle ascent phasing is required. After the shuttle accomplishes rendezvous with the core module, the station-shuttle adapter is deployed and berthed to the shuttle passenger port by use of the shuttle manipulator. The shuttle manipulator is then used to berth the orbiting core module to the station-shuttle adapter. The power module is then berthed to the core module using the shuttle manipulator (Figure 3-2). The core module-power module interfaces are connected and verified and the module cluster is prepared for quiescent operations. Before deploying the module cluster in a gravity-gradient flight mode, the core module is reberthed to the station-shuttle adapter at the minus X-axis port (opposite power module) where the adapter remains attached to the core module for all subsequent operations.

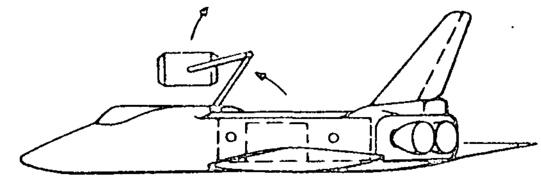
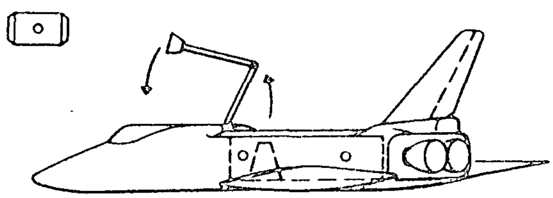
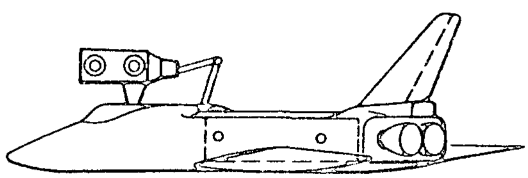
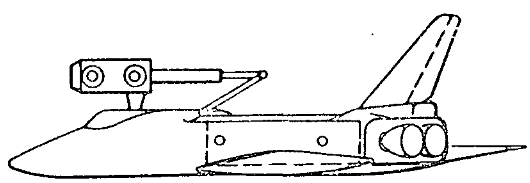
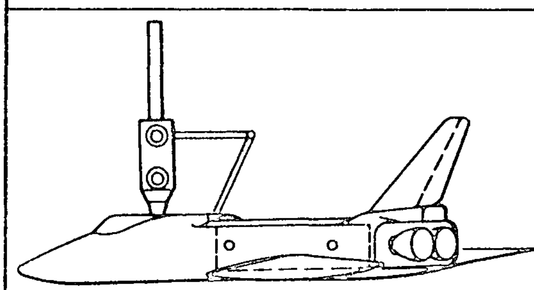
MODULE DELIVERED	PRINCIPAL OPERATIONS		ORBITAL CONFIGURATION
CORE		• ACTIVATE • CHECKOUT • DEPLOY	 CORE
POWER		• REMOVE AND BERTH STATION-SHUTTLE ADAPTER	 POWER
		• ATTACH MANIPULATOR TO CORE MODULE AND BERTH TO STATION-SHUTTLE ADAPTER	
		• REMOVE POWER MODULE AND BERTH TO CORE MODULE	
		• REBERTH CORE AND POWER MODULE CLUSTER TO STATION-SHUTTLE ADAPTER • DEPLOY MODULE CLUSTER	

Figure 3-1. Initial Space Station Buildup Sequence (Sheet 1 of 2)

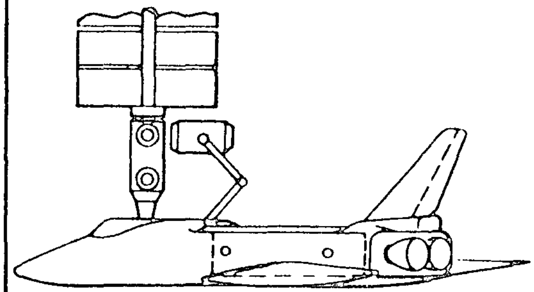
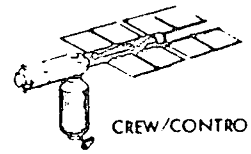
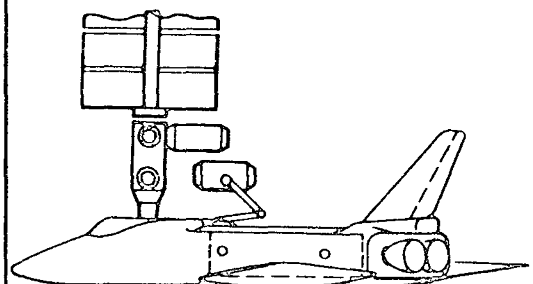
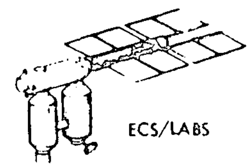
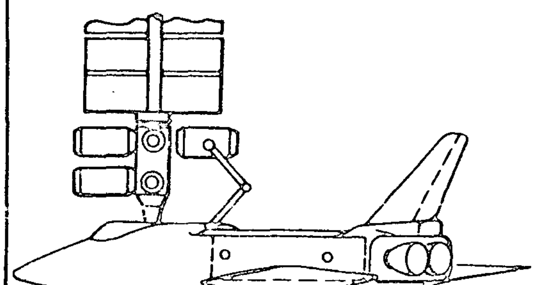
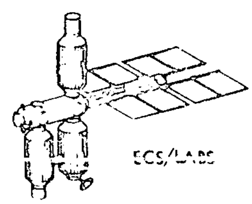
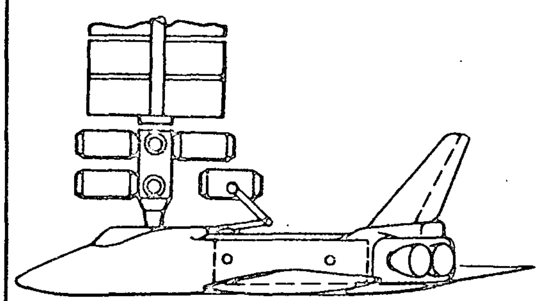
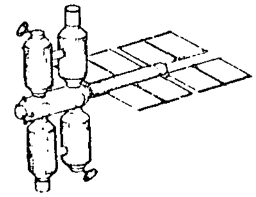
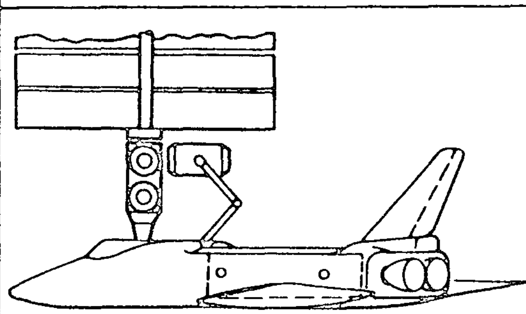
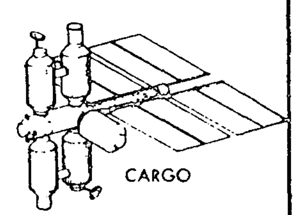
MODULE DELIVERED	PRINCIPAL OPERATIONS		RESULTANT CONFIGURATION
SM-1 (CREW/ CONTROL)		• BERTH CORE AND POWER MODULE CLUSTER • REMOVE SM-1 AND BERTH TO CORE MODULE • PARTIALLY ACTIVATE SM-1 • PARTIALLY DEPLOY SOLAR ARRAY (25%) • DEPLOY MODULE CLUSTER	 CREW/CONTROL
SM-2 (ECS/LABS)		• BERTH MODULE CLUSTER • REMOVE SM-2 AND BERTH TO CORE MODULE • PARTIALLY ACTIVATE SM-2 • DEPLOY MODULE CLUSTER	 ECS/LABS
SM-3 (ECS/LABS)		• BERTH MODULE CLUSTER • REMOVE SM-3 AND BERTH TO CORE MODULE • PARTIALLY ACTIVATE SM-3 • DEPLOY MODULE CLUSTER	 ECS/LABS
SM-4 (CREW/ CONTROL)		• BERTH MODULE CLUSTER • REMOVE SM-4 AND BERTH TO CORE MODULE • PARTIALLY ACTIVATE SM-4 • DEPLOY MODULE CLUSTER	CREW/CONTROL 
CARGO MODULE		• BERTH MODULE CLUSTER • FULLY DEPLOY SOLAR ARRAY • REMOVE CARGO MODULE AND BERTH TO CORE MODULE • FULLY ACTIVATE INITIAL SPACE STATION • DEPLOY INITIAL SPACE STATION • COMMENCE ROUTINE SPACE STATION OPERATIONS	 CARGO

Figure 3-1. Initial Space Station Buildup Sequence (Sheet 2 of 2)

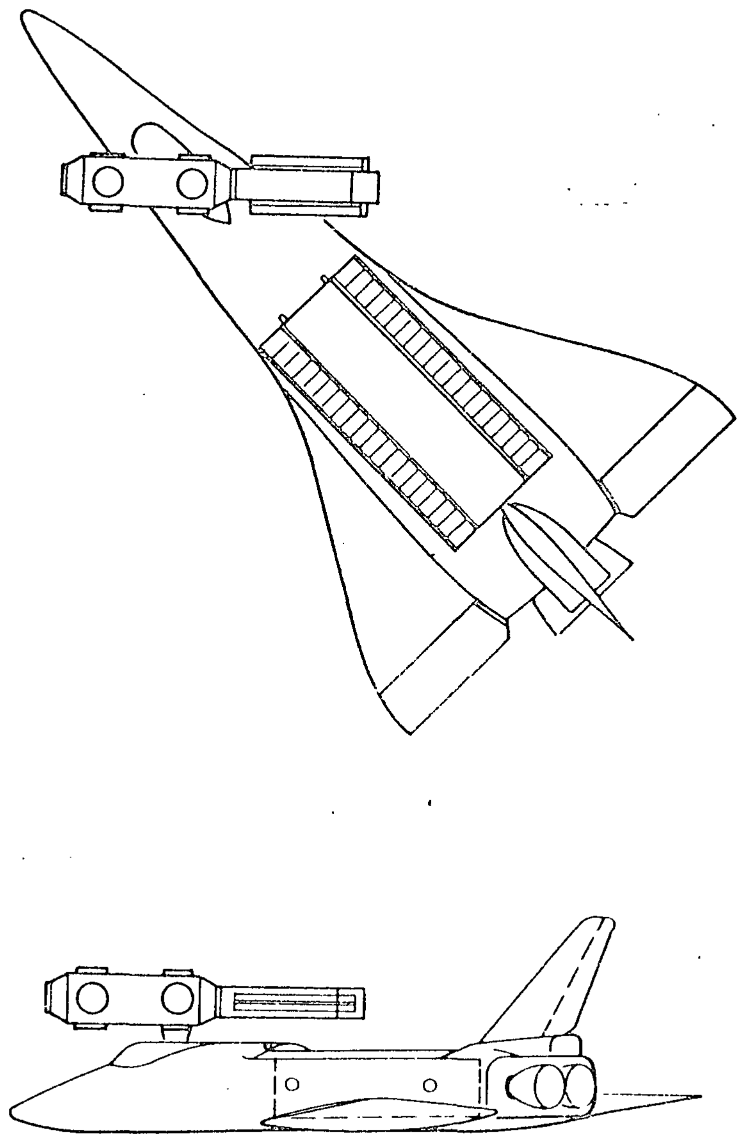


Figure 3-2. Power Module Berthing

Following orbital assembly of the core and power modules, the remaining station modules are delivered and berthed to the core module. The operations for delivery of the first control-crew module (SM-1) are summarized in Figure 3-3. The operations shown are representative of the buildup operations of all subsequent modules. In all cases, the shuttle performs rendezvous with the orbiting cluster and berths the cluster to the shuttle passenger port. The habitability of the module cluster is verified, the module being delivered is berthed to the appropriate core module port, and the interfaces are manually connected and verified. Following verification of the interfaces, the modules are activated to the level necessary for the remaining buildup operations. The module cluster is then configured for unmanned operations, and deployed using the shuttle manipulator.

The initial cargo module and the initial six-man space station crew are launched 180 days after launch of the core module. After the unmanned space station is berthed to the shuttle passenger port, the shuttle-space station interfaces and space station habitability are verified. The initial manning crew then enters the station, the solar array panels are fully deployed, both control centers are fully activated, and all subsystems brought up to operational status and verified. After the operational integrity of the station has been established, the cargo module is deployed and berthed to the core module by the shuttle manipulator. The station-cargo module interfaces are manually secured and the shuttle prepared for earth return. The cargo module stays with the station and acts as a supply center as well as providing a 96-hour emergency life support capability. The shuttle-station interfaces are manually disconnected, the shuttle performs a separation maneuver from the station and configures for earth return. At this time, approximately 185 days after the launch of the core module, the station is fully assembled, activated, manned, and capable of initiating routine operations.

The resultant orbital configuration of the space station at each stage of the buildup is shown in Figure 3-4. Upon completion of the buildup, the initial space station consists of the core module, power module, four station modules, and the initial cargo module. During the period of routine station operations, research and applications modules are delivered and berthed to the aft berthing ports as required to support experiment operations.

3.1.1.1.2.2 Shuttle Module Delivery Capability

The shuttle design reference mission (DRM) provides the capability to deliver a 25,000-pound payload to a 270-nautical mile 55-degree inclination orbit. The capability also exists to return an equivalent payload (e.g., delivery and return of cargo modules). This capability is associated with routine space station operations and is, therefore, based on a shuttle mission

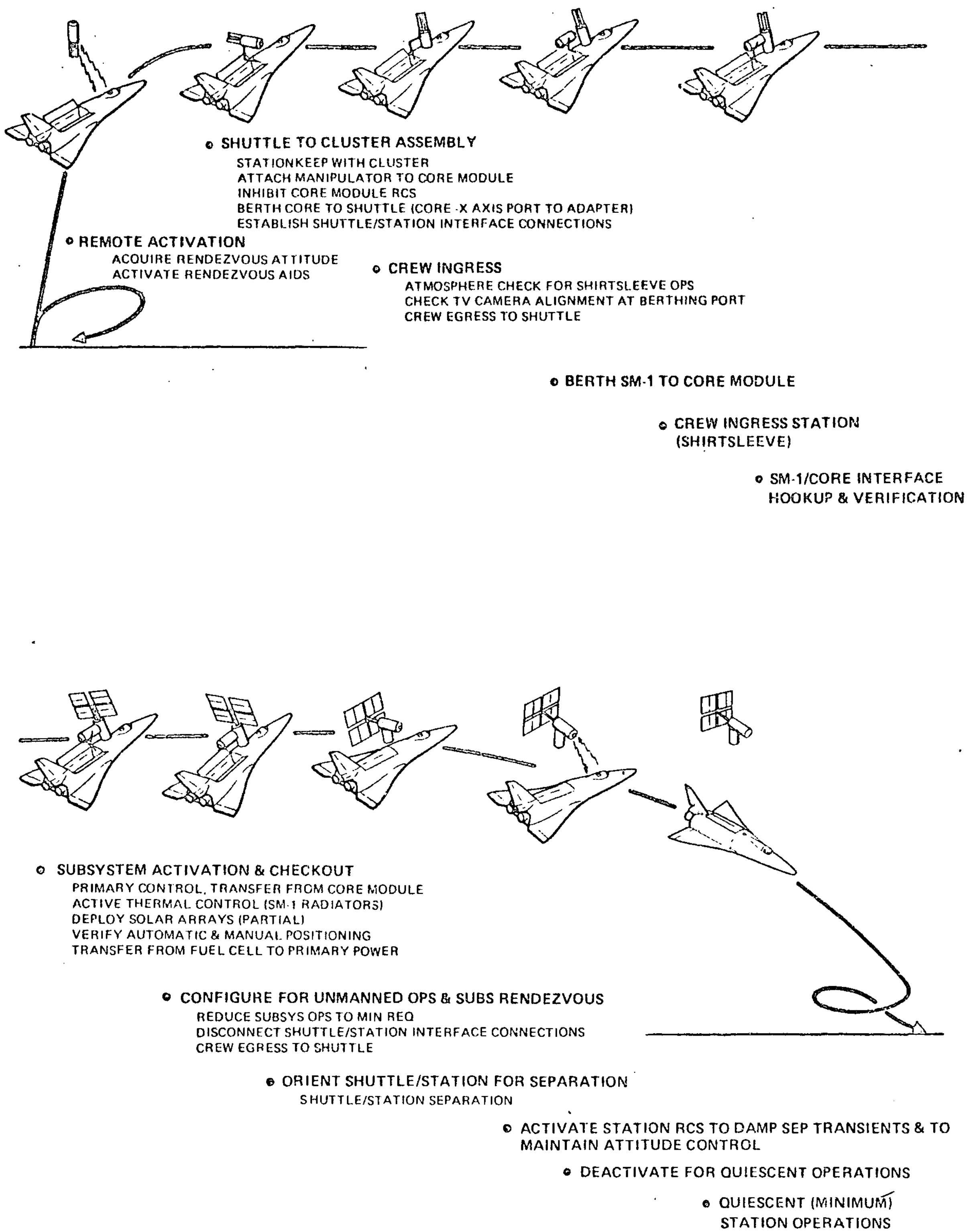


Figure 3-3. Typical Delivery Operations Sequence

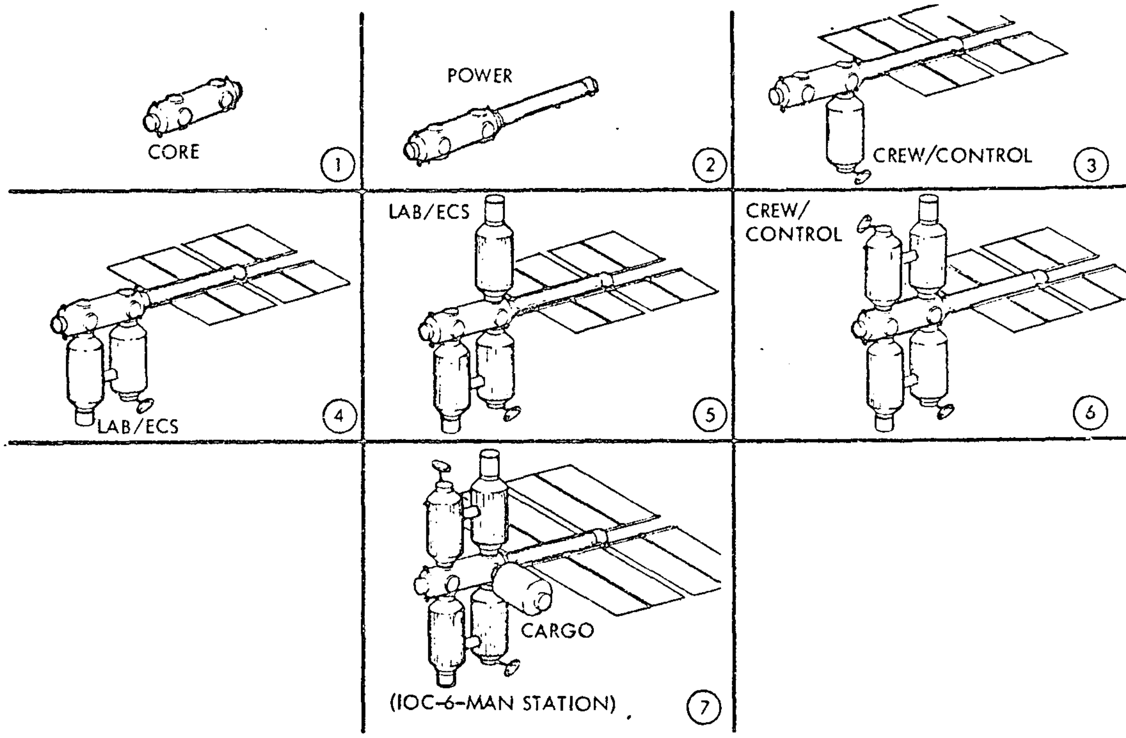


Figure 3-4. Initial Space Station Configuration Buildup

profile which includes rendezvous and berthing operations. These operations are not required for delivery of the first space station module resulting in a decrease in the on-orbit ΔV requirements. The reduced ΔV requirements decrease the propellant requirements (ACPS and OMS) by approximately 4,725 pounds, permitting a corresponding increase in the first module weight. The corresponding payload increase (Figure 3-5) permits the delivery of a 29,725-pound payload on the first module launch (including shuttle tariffs and weight growth margin allowance).

The source of the propellant reduction is shown in Table 3-1, which shows the shuttle DRM on-orbit propellant requirements and the reduced requirements associated with the first module delivery. The total shuttle DRM propellant requirement is 27,730 pounds, including 4,538 pounds for rendezvous and 467 pounds for berthing. The propellant requirement for the first module launch is reduced to 23,005 pounds by the elimination of the rendezvous and berthing propellant requirements while increasing the orbit injection propellant requirement. The increased orbit injection propellant is required to permit delivery of the first station module to 272 nautical miles since orbit makeup is not performed during the early phases of space station buildup. The first module is delivered to 272 nautical miles and allowed to decay during the first three months of the buildup operations.

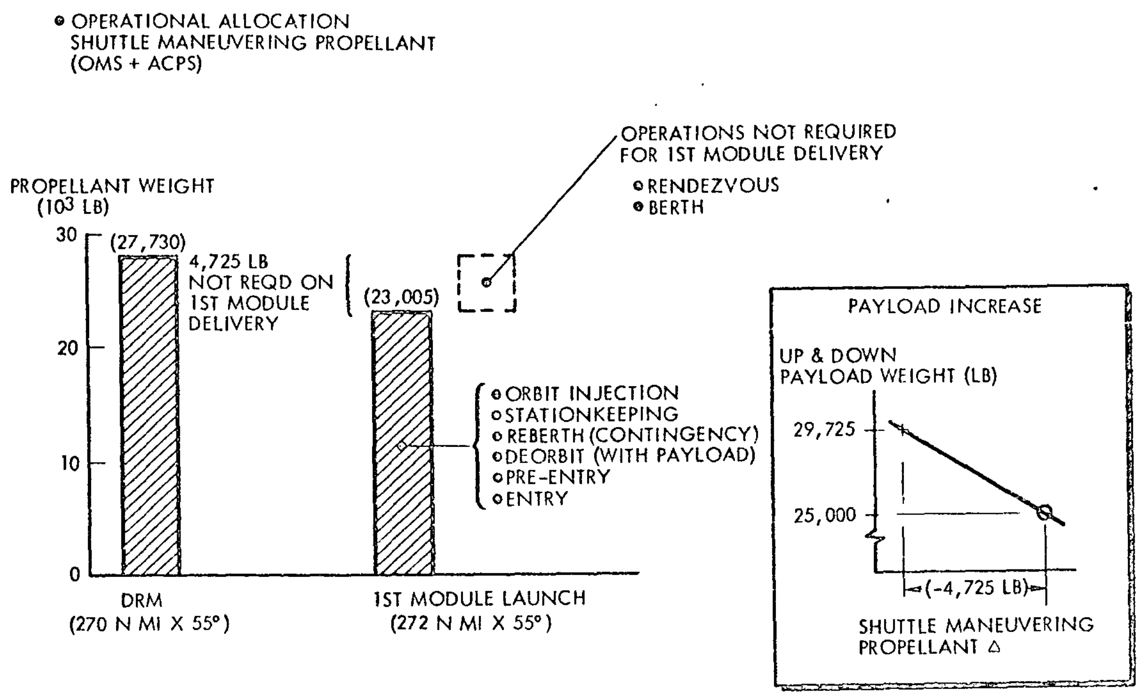


Figure 3-5. Shuttle First Module Launch Capability

Table 3-1. On-Orbit Propellant Requirements (First Module Delivery)

Mission Phase	On-Orbit Propellant Requirements			
	Shuttle DRM			
	ACPS (lb)	OMS (lb)	Total (lb)	Total (lb)
Orbit Injection	751	10,311	11,062	11,342
Rendezvous	1,242	3,296	4,538	-
Berthing	467	-	467	-
Stationkeeping (5 days)	694	-	694	694
Reberthing	622	-	622	622
Deorbit	254	8,744	8,998	8,998
Preentry	149	-	149	149
Entry	1,200	-	1,200	1,200
Total	5,379	22,351	27,730	23,005

Associated with the delivery of the space station modules are support items which must be charged against the shuttle payload. During buildup of the modular space station, these tariffs vary from 1,264 pounds for the core module to a maximum of 2,764 pounds for the power module. The tariffs for all modules and the tariff items are defined in Table 3-2. These tariffs effectively reduce the shuttle payload since the identified items are not inherently provided by the shuttle. As an example, delivery of the core module imposes a 1,264-pound tariff. The core module is the first station module for the selected buildup sequence. Therefore, the maximum allowable weight of the core module (including weight growth margin allowance) is 28,461 pounds. The corresponding maximum allowable module weights for all space station modules also are shown in Table 3-2. The weights shown, with the exception of the core module, are based on a 25,000-pound payload capability and, therefore, include any weight growth margin allowance.

Table 3-2. Shuttle Tariffs

Tariff Item	Tariff Weight (lb)					
	Core	Power	SM-1	SM-2	SM-3	SM-4
WBS Code	01	02	03	04	05	06
2 crew	400	400	400	400	400	400
2 crew provisions	300	300	300	300	300	300
2 PLSS and 2 PGA	354	354	354	354	354	354
Passenger provisions	63	155	190	160	160	166
Leakage makeup O_2 and N_2	0	165	180	210	210	210
Shuttle EPS reactants	50	365	495	383	383	405
Delta tank weight	97	425	425	425	425	425
MSS-shuttle adapter	na	600	na	na	na	na
Total	1,264	2,764	2,344	2,232	2,232	2,260
Maximum allowable module weight (including growth margin allowance)	28,461	22,236	22,656	22,768	22,768	22,740

3.1.1.1.2.3 Routine Operations

The routine operations phase constitutes the major modular space station operational phase and involves interfacing activities among the space station program elements, experiment program elements, and shuttle program elements. Routine operations commence following full space station activation and initial manning by a six-man crew and are completed when deactivation and disposition of the station is initiated. During this mission phase, the principal operational activities are:

1. Station Operations - Station operations involve the flight, administration/management, maintenance, and housekeeping operations which indirectly support the experiment operations and crew. Flight operations include communication, utility subsystem management, monitor and warning, and integral flight control. Administrative management operations include station command, data management, logistics inventory control, and crew care. Housekeeping operations include food management and preparation, cleaning, trash disposal, and cargo handling.

2. FPE Support Operations - FPE support operations consist of the crew and primary subsystem operations directly supporting the experiment operations. Among the primary subsystem operations are providing experiment electrical power, stability and control, environmental control, and data handling.

3. FPE Operations - Functional program element operations include the routine day-to-day scientific and engineering operations needed to perform the generic experiments specified by the NASA Blue Book. These operations involve the operation and control of integral experiments and of attached and detached RAM's.

3.1.1.1.2.4 Mission Sequence Plan (Typical)

The mission sequence plan provides the phasing of the program elements with emphasis on the scheduling of experiments. The mission sequence plan for the initial station is summarized in Figure 3-6, which presents the experiment phasing (length of bar), accommodation mode (by bar and module shading), and crew requirements (number of equivalent men per day symbols on bar). The experiment disciplines are presented in the order in which the FPE's are introduced into the program. The early FPE's in the physics and technology disciplines are precursors for measurement of the space station environment prior to the operations of external-viewing FPE's such as earth observations and astronomy. During the initial station period the first attached RAM is shown in operation in 1982 conducting high-energy stellar observations. The first detached RAM is accommodated in mid-1985 to conduct X-ray stellar observations.

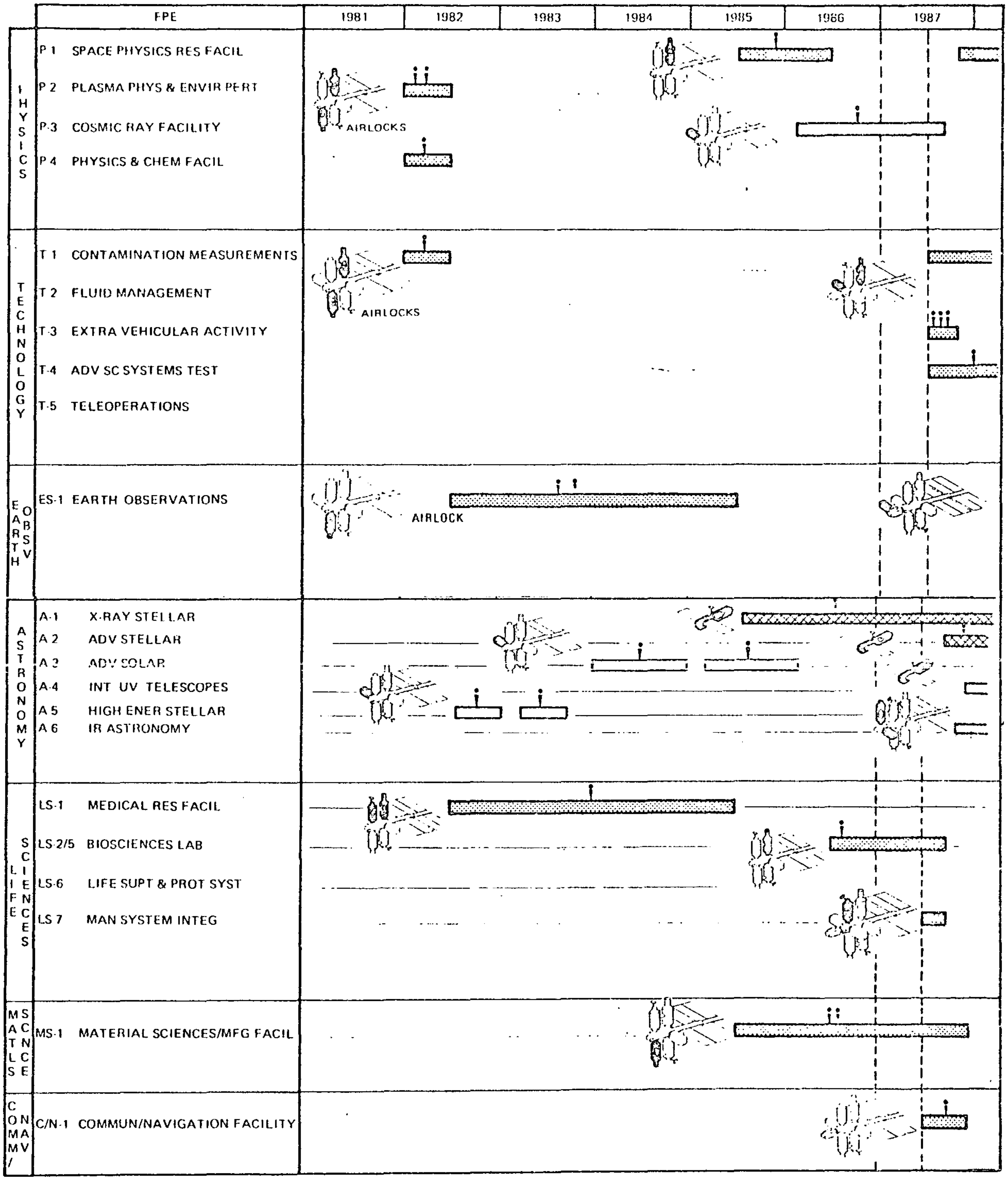


Figure 3-6. Mission Sequence Plan Summary (Typical)

The mission sequence plan, as presented, was developed assuming each FPE is operated for one cycle at each level of activity (Level II and Level III). In the laboratory evolution philosophy, Level I refers to that portion of a total facility concept which supports experiments of short duration (example: sortie missions of 7 to 30 days). Emphasis at Level I is placed on applications and precursor-type experiments. Level II adds equipment associated with long duration or permanent-type experiments emphasizing a balanced but low-cost program. At this level, partial experiment laboratory capabilities are provided. Level III consists of the total Blue Book facility (i. e., complete laboratory experiment capability is provided for a specific discipline). The growth space station provides this capability for all experiment disciplines.

The mission sequence plan presented and the associated experiment scheduling is intended to be representative of MSS operations. It is not intended to represent the experiment program which must be scheduled since the space station has the inherent capability and flexibility to accommodate alternative programs (e. g., one which emphasizes socio-economic benefits or one which emphasizes advancements in scientific knowledge.) The plan is intended to emphasize certain fundamental characteristics, however. For example, by defining an initial level of experiment activity (Level II), the majority of the FPE's can be accommodated early in the space station program while deferring some of the experiment equipment development costs until after the space station development peak annual funding. The Blue Book level of activity (Level III) is then deferred until the growth space station which provides a "facility capability" for accommodating the FPE's as defined by the Blue Book. In this respect, the plan illustrated the capability of the selected design concept to accommodate the Blue Book in a balanced program in which all disciplines are represented throughout the program.

3.1.1.1.2.5 Crew Operations

The initial space station operations require 25 man-hours per day. These operations include the routine daily operations of the space station, routine and periodic maintenance, housekeeping, monitoring and control of detached RAM's, etc. The experiment operations are those associated with the daily conduct of the space station experiments. Based on 25 man-hours per day for station and support operations and a six-man, 10-hour work day, approximately 35 man-hours per day are available for experiment operations for the initial space station.

Fifteen crew skills have been identified for the conduct of experiment operations (Table 3-3). In the early phases of the initial space station operations, only four skills are required for experiment operations resulting in approximately 1.1 skills per crewman. During the remaining operations of the initial station, the average number of skills for experiment operations is eight, resulting in a requirement for approximately 2.4 skills per crewman.

Table 3-3. Crew Skills Distribution for Initial Space Station (Typical)

Skill	No. Crewmen (First Date Required)						
	1-3 (1/82)	4-9 (7/82)	10-14 (12/83)	15-16 (7/85)	17 (2/86)	18 (5/86)	19 (8/86)
Biological technician		X	X	X	X	X	X
Microbiological technician		X	X			X	X
Biochemist		X	X			X	X
Astronomer/ astrophysicist		X		X	X	X	X
Physicist	X	X	X	X	X	X	
Nuclear physicist					X		
Thermodynamicist	X						X
Electronic engineer		X					
Electromechanical technician	X	X	X	X	X	X	X
Medical doctor		X	X				
Optical technician		X	X	X	X	X	X
Optical scientist			X				
Chemical technician				X	X	X	X
Material scientist				X	X	X	X
Physical chemist	X						

3.1.1.1.2.6 Ground Operations

A typical sequence of operations through the launch and recovery site is shown in Figure 3-7. The modules arrive at the launch site at the shuttle runway, either delivered from the factory or returned from orbit. When returned from orbit, they are removed from the orbiter in the Vertical Assembly Building (VAB) and transported to the Manned Space Operations Building (MSOB) for servicing. Cargo is loaded into the cargo modules in the warehouse and weight and balance operations are accomplished in the MSOB. The modules are installed in the orbiter in the VAB, then the shuttle is transferred to the pad for launch operations.

The MSS modules delivered from the factory will arrive at KSC by air (Guppy). The longitudinal (X) and transverse (Y) axes of the modules will be in a horizontal position all during shipment and transport to the MSOB. The modules will be moved to the MSOB utilizing the module transporter.

MSOB Receiving Inspection. Receiving inspection will consist of a visual inspection of all interface details, using standard inspection aids. The berthing port interface checkout stand, in conjunction with peripheral ground support equipment and Universal test equipment (UTE) will then be utilized for an electrical interface verification test to determine gross status of the module. This test will include standard checks such as continuity, resistance, polarity, and will satisfy the mechanical docking interface checkout requirement. No fluid servicing or activation is anticipated unless the radiators have been drained prior to air transportation. If this is the case, the external coolant loop must be filled, activated to exclude all entrapped air, and sealed for orbital operations.

If the gross status check is satisfactory, the flight modules will proceed to a second mechanical docking interface test with an orbiter docking simulator. This simulator must be capable of simulating disconnect commands as well as the electrical power to actuate the unlocking mechanism.

MSOB Flight Module Acceptance (SM-3, SM-4, and cargo modules). If the receiving inspection is satisfactory, the module will be docked to the mission support vehicle (MSV), hose and cable jumpers attached, and the module powered up per operating procedures.

The subsystem and sensor checkout will be accomplished utilizing whatever MSV systems are required to be powered-up for the particular test in process. Except for the cargo modules, which will be transferred to the cargo loading, the modules will be transported directly to the shuttle maintenance and checkout facility for loading into the orbiter at approximately 20 hours prior to rollout to the pad. The loading will be accomplished in the Vehicle Assembly Building.

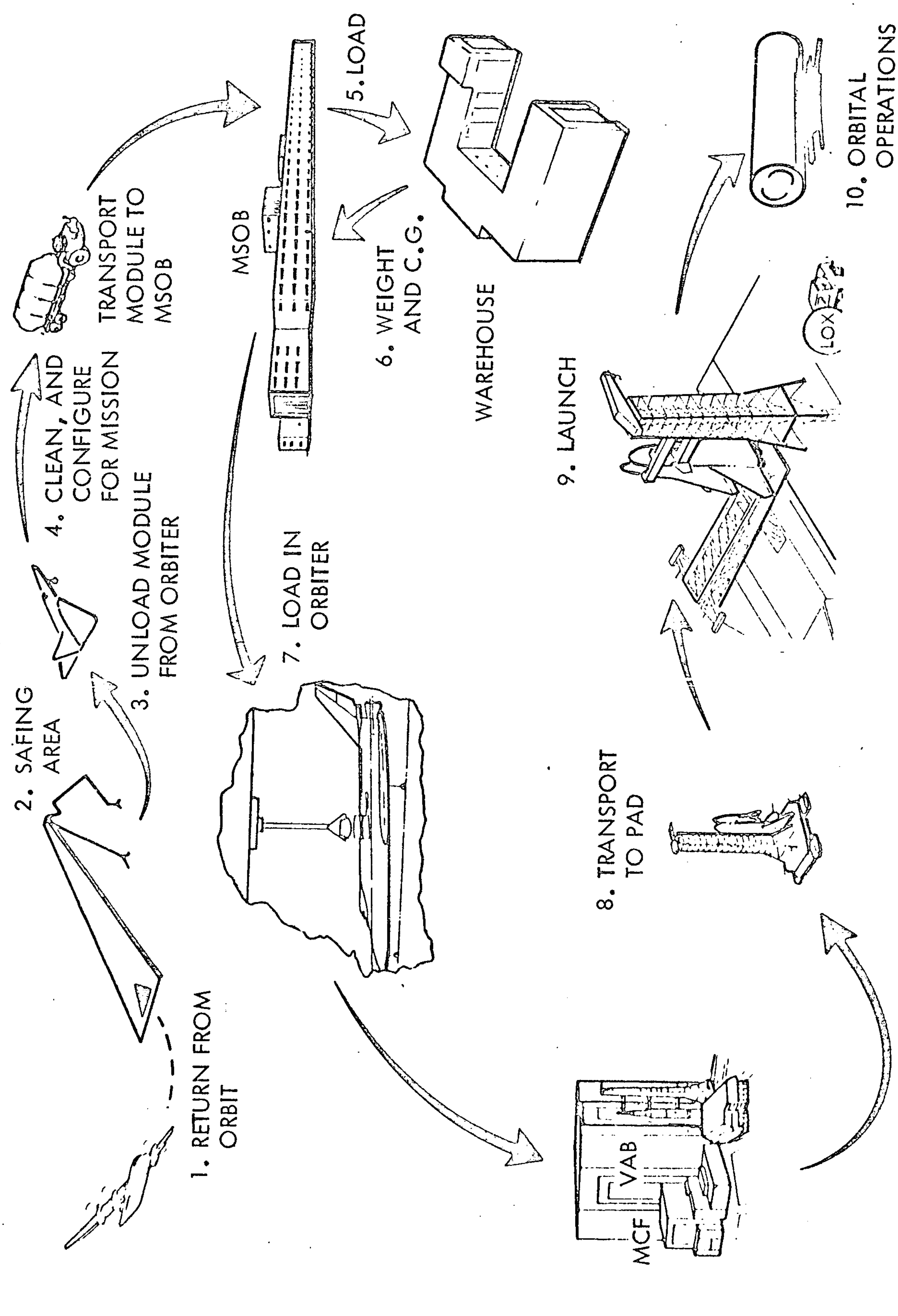


Figure 3-7. MSS Program Element Operations

Orbiter Loading at VAB. The modules will be hoisted above the orbiter and lowered horizontally into the cargo bay, maintaining an attitude compatible with that of the orbiter. After the module is fully lowered, the aft interface is established and the orbiter cargo retainer and centering device is engaged.

The crew in the orbiter cockpit will make all necessary checks of subsystem continuity and position indicators. After all checks have been made, the installation GSE is removed from the cargo bay and the bay doors closed. After installation operations have been completed, the access workstands will be removed and no further activity is planned until after the rollout is completed.

Launch Pad Operations. The shuttle vehicle and launch umbilical tower (LUT) will be transferred to the launch pad by the crawler-transporter. At the launch pad, the LUT is secured to the pedestals, shuttle to ground service connections are made, and the MSS modules checked for preflight readiness.

When electrical power is available, status checks will be made in preparation for the mission readiness test. A final data review will be conducted after this test and completed prior to commencement of the launch countdown.

Launch operations begin with the loading of cryogenic propellants (LO_2 and LH_2) into the shuttle booster and orbiter. Propellants are replenished until the final stages of countdown operation. Final system activation and countdown operations are performed. Both airborne and ground systems are monitored for abort conditions that may occur anytime during launch operations. The launch countdown time line is shown in Figure 3-8.

The launch pad area will be cleared of all personnel prior to loading propellants. Childown of transfer lines and shuttle tankage, venting, transfer of propellants, replenishment, and termination are accomplished by an automated system with contingency pause and revert capability. After childown, simultaneous loading of LO_2 and LH_2 into the booster, orbiter, and payload (if required) will begin. The first phase of the loading after tank childown is a "fine load" (low rate of flow) followed by "rapid load" (high rate of flow). Completion of propellant loading is accomplished with another fine-load sequence.

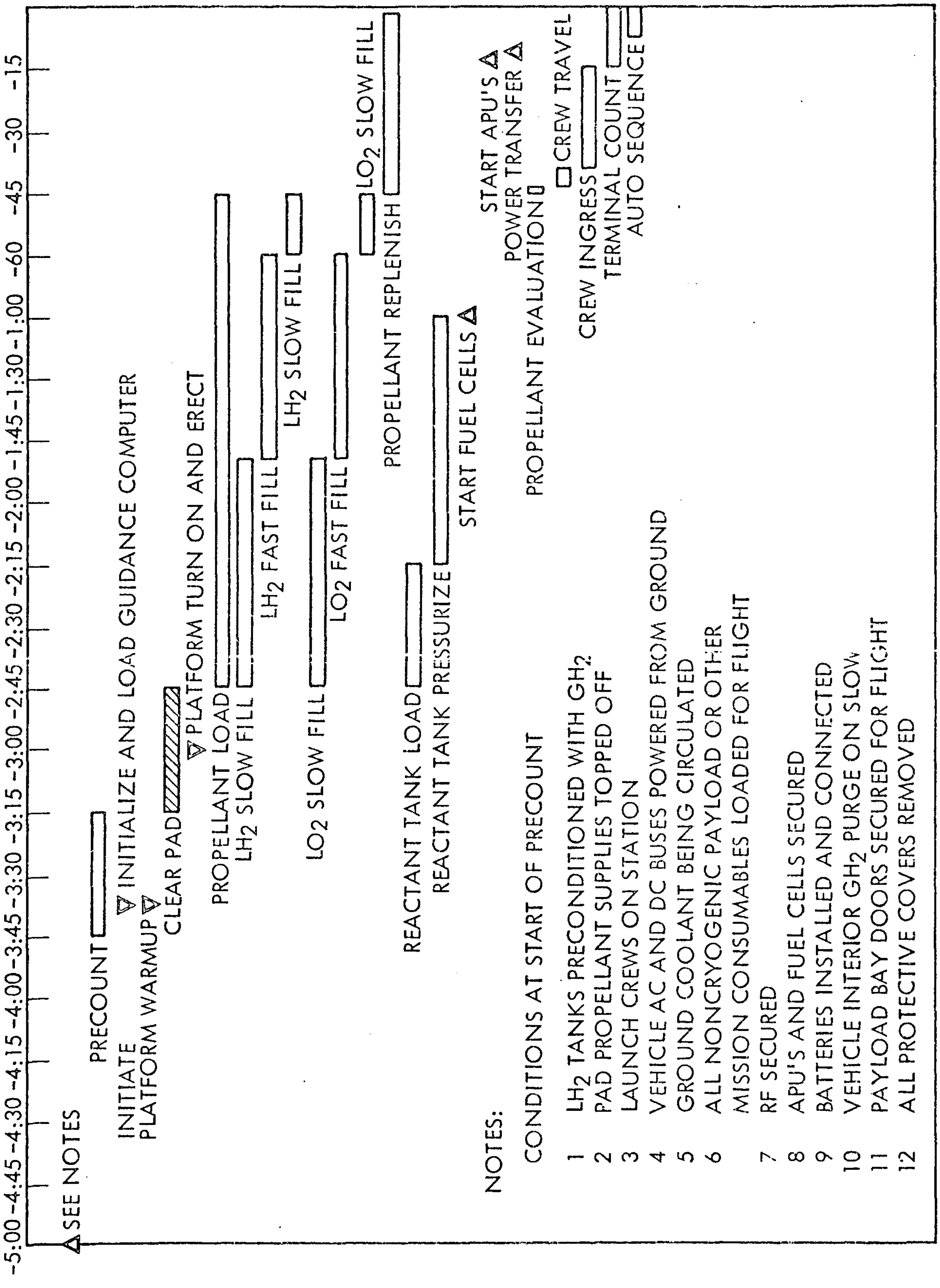


Figure 3-8. Shuttle Countdown Timeline

Airborne level-sensing transducers, in conjunction with the ground computer system and ground transducers, will control the entire automated loading sequence. Remote control and display capability will be used throughout the countdown to monitor propellant loading operations. After propellants are loaded, the flight personnel are transported to the launch site and board the vehicle.

Pressurization of the reactant storage tanks will be initiated as soon as practical. As soon as single phase conditions are achieved, the fuel cells will be started.

The launch pad facility will have a rapid-lift elevator within the service tower to transport shuttle crew members, space station passengers, and the closeout crew to the boarding platform access arms. It must be noted that the up passengers will generally be limited to six persons. The flight crews will board prior to passenger loading. The closeout crew will assure that each passenger and flight crew member is secured and ready for launch. The access arms will be moved to a standby position just clear of the booster and orbiter when the hatches are closed and the closeout crew has moved back to a safe area.

The launch vehicles and the launch pad service tower design will incorporate emergency egress capabilities for the flight crews, passengers, and other personnel during launch operations. This capability will be sustained as close to launch as possible. In addition, the launch facility will provide personnel safing areas to protect the crew, passengers, tower, and rescue team personnel from possible hazards.

Launch Countdown. With the completion of the crew boarding operations, the terminal countdown will be performed. The launch countdown checklist will be called up by the flight crews and displayed.

Airborne systems will be automatically scanned for proper configuration and readiness for launch. The range safety officer will verify that the range is clear for launch. The mission director will determine that all mission criteria have been satisfied and will issue the clearance to launch.

The crew will then verify that the ready-for-launch summary is present from all subsystems.

The launch program will be initiated by the shuttle flight crew. The launch sequence will progress automatically from this point to liftoff. During this sequence, the propellant replenishment will be terminated, the propellant tanks pressurized, the ground pneumatic system isolated, and the booster engines ignited. When an intermediate thrust level is reached, an evaluation of propulsion system performance will be made, a signal will be transmitted to release the vehicle stabilizing system, and the thrust level will be commanded to go to normal. When the thrust-to-weight ratio is greater than 1.0, the space shuttle achieves a free liftoff and rises from the launch pad, and simultaneously activates the liftoff signal.

Recovery Area. Postlanding operations (recovery) include the functions of crew and passenger egress removal, and preparation for maintenance.

After landing and clearing the runway, the orbiter flight crew will initiate onboard safing procedures and shut down the subsystems. The orbiter will then be taxied or towed to the safing area for passenger and crew egress.

The orbiter will be safed and serviced in the safing area. This will include propellant detanking, purging, and venting. Preliminary visual inspections will be initiated during this time.

After the orbiter has been defueled, purged, safed, and the necessary preliminary inspection completed, the cargo bay doors will be closed and the vehicle towed to the maintenance and checkout facility located at the modified VAB. After positioning in the maintenance bay, the work stands will be positioned, the cargo bay doors opened again, and the module removed with the facility crane. The module will then be transported to the MSOB or warehouse (in the case of the cargo module) by means of the module transporter.

Maintenance and Refurbishment. Maintenance operations comprise the functions and activities from the conclusion of postlanding safing and servicing to prelaunch operations.

Scheduled maintenance will include activities required for modification of basic structure and passenger equipment such as seats, EVA equipment, emergency equipment, food, water, waste management provisions, tools and other mission-related equipment. Trend data will determine (from the evaluation of the onboard recorded flight data) the scheduled replacement of subsystem assemblies and components. Inspection performed during this activity may disclose requirements for unscheduled maintenance.

Major modifications may require recycling the modules to the MSV to verify interface compatibility and confirm revisions to station operating procedures.

Unscheduled maintenance will be controlled largely by recorded flight data and crew reports. Analysis of these data will be used to identify unscheduled maintenance activities, and when integrated with trend data, will provide a basis for changes in scheduled maintenance activities.

3.1.1.1.3 Project Interfaces

3.1.1.1.3.1 MSS Project-Shuttle Project

The following paragraphs contain the overall interface requirements between the modular space station project and the shuttle project. For more detail refer to the MSS Shuttle Interface Requirements document (SD 71-221, MSC-02474).

The shuttle self-sustaining mission duration shall be seven days (from liftoff to landing).

The space shuttle shall have the capability to launch northeasterly and southeasterly to achieve rendezvous with the space station in a 55-degree inclination orbit.

The shuttle shall provide safe mission termination capability. This includes rapid crew and passenger egress before liftoff and intact abort after liftoff. Intact abort implies the capability of the booster and orbiter to separate and continue flight to a safe landing, the orbiter to land with a full payload.

The orbiter shall have sufficient propellant to provide 1500 fps on-orbit ΔV capability (in excess of amount required to attain the design insertion orbit) with a maximum payload for the 270-nautical mile at 55-degree inclination reference mission. The tanks shall be sized to provide 2000-fps ΔV capability.

MSS modules shall be designed to interface with the standard orbiter deployment provisions. The orbiter will provide the capability to retain modules in the cargo bay and to deploy the module out of the cargo bay.

The orbiter shall perform rendezvous and docking maneuvers and shall be capable of berthing with a stable module or station. The modular space station shall maintain a stable attitude for berthing.

The orbiter crew and passenger compartment shall provide a shirt-sleeve environment compatible with the modular space station environment for the shuttle crew and station passengers.

Modular space station modules shall be designed so that they may be transported by the orbiter without modification and extensive payload-transport integration or testing. The orbiter shall be designed and developed to enable the transport of modules without extensive integrated operational buildup or extensive development testing.

The space station program shall not be required to provide payloads for both the up and down legs of any single shuttle cycle. The space shuttle program shall supply an operational capability over the entire range from zero to maximum payload.

The orbiter shall be capable of the active role in rendezvous with the station and shall provide suitable braking or wave-off capability in the event of a runaway thruster or similar malfunction.

The status of module life critical functions (atmosphere content, pressure, temperature) shall be monitored by the orbiter prior to berthing and confirmed by visual display at the entry hatch before the initial inspection or activation crew are transferred from the orbiter.

During initial MSS orbital buildup operations the orbiter shall remain berthed to and in control of the modules while crewmen are on board and until it is determined that the configuration is operational.

The orbiter shall minimize the release of liquid or gaseous products in the vicinity of the space station. The space station shall be designed and operated to minimize the effect of the environmental contamination introduced by the orbiter.

The shuttle shall provide the capability to perform rescue operations (including station personnel transfer) within 48 hours. The modular space station system shall provide the capability for 96 hours of emergency operations.

The cargo bay shall be sized to have clear volume of 15 feet in diameter by 60 feet in length. Payloads shall be equal to or less than 15 feet in diameter and 60 feet in length including rings, attachment fittings for the deployment mechanism and berthing, and cargo bay storage fittings. The standardized deployment mechanisms and tie points shall be chargeable to the orbiter and shall not occupy the clear volume. Deployment clearance shall be provided by the orbiter.

Modules normally shall be loaded and unloaded within the orbiter in the horizontal position.

The orbiter shall be capable of providing for topping and dumping of hazardous fluids and gases for all space station program modules.

The orbiter shall provide, before fueling, access to the MSS modules in the cargo bay for late-in-the-count loading of critical cargo. The MSS project shall minimize and identify late-load cargo requirements.

The orbiter shall be capable of monitoring critical module functions which may be potentially hazardous. Modular Space Station Program modules shall provide onboard capability to monitor critical functions to enable the status to be determined by the orbiter. MSS Program modules shall provide appropriate warning signals to the orbiter interfaces for imminent peril originating from or identified from the payload side of the orbiter interface.

The orbiter shall provide rapid egress for all payload passengers, support, service, or launch crews from the program hardware interface to a safe area or position.

The orbiter shall provide ground electrical and fluid interface provisions for station modules. Station modules shall be constrained to utilize ground electrical and fluid connections provided in the orbiter.

The orbiter project shall provide electrical power to the cargo bay payload interface during all mission phases from cargo insertion to completion of the mission as identified by the space station project. The space station project shall identify electrical power required in the orbiter cargo bay for all mission phases and shall provide an electrical interface compatible with the orbiter.

The orbiter shall provide for the access to and removal of payload modules in the horizontal position after orbiter landing. Payload modules shall be designed to facilitate access and removal in the horizontal position from the cargo bay after orbiter landing.

During initial MSS orbital operations the shuttle shall be capable of transmitting selected RF commands. The MSS shall be capable of receiving and responding to such RF commands.

3.1.1.1.3.2 MSS Project-Experiment Project

The results of the experiment project analyses are contained in Volume 3 of the MSS Preliminary System Design (SD 71-217-3, DRL 68). As part of this analysis, the requirements associated with particular experiment programs were verified against the MSS capabilities. As the mix of experiments changes, the quantitative detailed requirements vary. Therefore, the MSS capabilities were used to define the quantitative interface requirements.

The initial space station will be operational when fully manned (six crewmen) and fully configured with a general-purpose laboratory (GPL) with the capability to accommodate at least two attached or detached RAM's.

The initial MSS shall be capable of supporting selected, partial, modified, or combined FPE's from the Blue Book. Blue Book experiments and RAM's are to be scheduled in accordance with station capability. Modified FPE's will require approval of NASA.

The experiment equipment shall protect against small animal waste and other bioscience experiment particulate matter from entering habitable areas of the space station which could result in contamination of these areas.

The MSS shall provide the following support capability at the general-purpose laboratory (GPL) or RAM interfaces:

1. Floor area (GPL)

Medical/biological Physics	177 sq ft (typical) Shared but not simultaneously
Mechanical maintenance Electrical/electronic maintenance Optical supply and maintenance	273 sq ft
Data analysis	177 sq ft
Photo processing	33 sq ft
Experiment operations	164 sq ft
Total	824 sq ft

2. Electrical power (GPL and Attached RAM's)

24-hour average	4.5 kw
Peak power sustained for one hour or one hour cumulative time in any 12-hour period	7.0 kw

3. Environmental control and life support subsystem (GPL and RAM's)

Habitable experiment areas	Shirtsleeve
Airlock (experiment) pressurization/depressurization frequency	5 per month
RAM pumpdown and repressurization	Experiment provided
RAM leakage makeup	1 lb/day

RAM atmospheric circulation at interface	100 lb/hour max
Atmospheric pressure control	14.7 psia
Humidity control (above crew)	0.1 lb/day
Contamination control	None
Experiment atmospheric thermal load	Experiment provided
Water coolant	4.5 kw
Potable water for experiment	35 lb/day max
Waste management	67 lb/mo
Hygiene - experiment	Experiment provided
Food management - experiment	Experiment provided

4. Guidance and control

Attitude hold	
Nadir and inertial	±0.5 deg
Fine pointing	±0.1 deg for 30 min
Stability	
Angular rate limit	0.05 deg/sec
Fine pointing	0.01 deg/sec
Instant attitude knowledge	0.10 deg
Station position ephemeris	
Altitude	±1500 ft (1 sigma)
In track	±3800 ft (1 sigma)
Cross track	±2200 ft (1 sigma)
Orbital velocity	±3.5 fps
Experiment angular impulse	
24-hour average	10,000 ft-lb-sec
Experiment torque	100 ft-lb
Operational accelerations	
Control moment gyro (CMG) desaturation and orbit makeup	1.4 x 10(-4) g maximum for 140 sec

Berthing	4.0 x 10(-2)g maximum for 0.3 sec
Quiescent - 6 hours continuous	10(-4) g maximum
- 2 hours continuous	10(-5) g maximum

5. Information subsystem

Communication - external

Voice - full duplex	4 channels maximum
Experiment telemetry - detached RAM to MSS	2 channels
Experiment telemetry - MSS to ground	1 channel real time
Experiment control - MSS to detached RAM	2 channels simplex
Digital text/facsimile	1 channel
TV - black and white or color - MSS to ground	1 channel
TV - black and white DRAM to MSS	2 channels

Communication - internal

Voice - private/conference/PA	3 channels
Closed-circuit television (CCTV) - black and white or color	7 channels
Record/playback	Audio/video/digital real time

Tracking - detached RAM's 450 n.mi. to 1000 ft	±500 ft/0.5 fps

Data processing

Data acquisition	2 mbps
Storage	1 archive recorder
Processing rate	1.045×10^6 operation/sec

6. Crew Manpower (GPL and RAM's)

Dedicated to experiments — 35 hours per day

The MSS shall provide the following experiment support functions as part of the base GPL configuration.

Experiment No.	Support Function	Laboratory Area
A015	Analysis, hydrocarbon	Biological/biomedical
A016	Analysis, nitrogen	Biological/biomedical
A017	Airlock provision	Physics
C005	Cell counting	Biological/biomedical
C006	Colorimetry	Biological/biomedical
C007	Cytological stain preparation	Biological/biomedical
C009	Culturing, bacteria	Biological/biomedical
C022	Cryogenic storage	Fluid systems test/maint.
C029	Centrifuge clinical (GD)	Biological/biomedical
D014	Data retrieval/viewing	Data analysis
H001	Histology	Biological/biomedical
L002	Lighting, photo, and TV	Optical supply/maintenance
L005	Lyophilization	Biological/biomedical
M001	Maintenance and calibration mechanical	Mechanical maintenance
M002	Maintenance and calibration electrical	Electrical maintenance
M003	Maintenance and calibration optical	Optical supply/maintenance

Experiment No.	Support Function	Laboratory Area
M004	Maintenance and calibration fluid systems	Fluid system test/ maintenance
P002	Photography, cine - int	Optical supply/ maintenance
P003	Photography, still	Optical supply/ maintenance
P011	Photographic processing	Photo processing
P013	Preservation, culture (refrigeration)	Biological/biomedical
P014	Preservation, culture (oven)	Biological/biomedical
R00A	Reflectometer, portable-measuring	Physics
S008	Spectrometry, mass	Physics
S017	Sterilization	Biological/biomedical
V004	Viewing airlock window	Physics

3.1.1.1.3.3 MSS Project-tracking and Data Relay Satellite (TDRS) Project

Table 3-4 delineates the physical and functional interface characteristics of the TDRS equatorial-synchronous satellite. It is this interface with which all NASA orbital programs must be compatible

Table 3-4. TDRS Interface Characteristics

Item	Quantitative Value
Physical	
Number of satellites	2 + 1 on-orbit spare
Location of satellites	15 degrees west 145 degrees west (spare somewhere between)
Location of ground station	Goddard Space Flight Center (GSFC)
Location of communication switching center	Locate with mission control center
Systems	VHF
Functional	
Transmission frequency (satellite to spacecraft)	
VHF	126 - 130 MHz
K_u	13.4 - 14.2 GHz
Reverse link (spacecraft through satellite to ground)	
VHF	136 - 144 MHz
K_u	14.4 - 15.35 GHz
K_u band maximum data capability (one dedicated link)	50 mbps or analog equivalent tracking
VHF capability	
Voice	2 duplex
Data/command	5 kbps (substituted for voice links)

Transmit and receive modes shall be available in the combinations depicted in the Tables 3-5 and 3-6. Primary modes required between the MSS and the ground network via the TDRS are specified in Table 3-4. Primary modes required between the ground network and the MSS via the TDRS are specified in Table 3-6.

Table 3-5. MSS to TDRS Modes

Function	Combinations								
	1	2	3	4	5	6	7	8	9
Voice	X	X	X	X	X	X	X	X	X
Facsimile		X					X		
System telemetry			X					X	
Ranging, pseudrandom noise (PRN)				X					
Experiment telemetry					X				X*
TV black and white or color						X	X	X	X

*Limit 50 kbps

Table 3-6. TDRS to MSS Modes

Function	Combinations							
	1	2	3	4	5	6	7	8
Voice*	X	X	X	X	X	X	X	X
Control		X				X		X
Computer Data			X				X	X
Text/graphics				X				
Ranging (PRN)					X	X	X	

*Includes music

3.1.1.2 Logistics

3.1.1.2.1 Logistics Considerations

Logistics support of the space station will be required once the buildup operations have been completed. The required support operations include the delivery and return of space station crewmen, experiment equipment, consumables, spares, and RAM's. The scheduling of these operations depends on the scheduling of the space station operations defined by the mission sequence plan (MSS Preliminary System Design, Volume II; SD 71-217-2, DRL 68). A typical mission sequence plan, summarized in Figure 3-6, provides the phasing of all program elements including the shuttle support requirements. The mission sequence plan defines the schedule for delivery of the station modules, delivery and return of cargo modules, and delivery and return of space station crewmen. It also defines the scheduling of all FPE's identified in the 1971 Blue Book. The logistics support requirements, which will be discussed in further detail, are summarized as well as the scheduling of all shuttle launches.

The resultant operational program for the initial space station has a duration of approximately 5.5 years from the first space station module launch to completion of initial experiment operations. Six months are required for initial station buildup with IOC occurring in January 1982. The station operates at a six-man level while experiments are conducted in six of the seven experiment disciplines. Initial operations are primarily conducted in the general-purpose laboratory (GPL); however, the first attached RAM is introduced midway into the first year of experiment operations and the first detached RAM is launched in the fourth year.

The logistics requirements necessary to support the initial space station operations and the experiment program defined by the Mission Sequence Plan are shown in Table 3-7. Approximately 1900 pounds per month are required for basic operations of the initial space station. Based on the experiment scheduling previously identified, approximately 1,000 pounds per month are required for operations of the initial space station experiments. The experiment logistics requirements shown are an average value of the requirements for consumables and experiment equipment which must be delivered during the operation of the space station. An additional logistics requirement is imposed by the need for oxygen and nitrogen for emergency operations. The resultant cumulative requirements are shown in Figure 3-9, where the lower line represents the cumulative requirements for basic station operations and the upper line represents the total including experiment operations.

The resultant shuttle requirements for support of the space station are summarized in Table 3-8—in terms of the missions required for the delivery of station modules (crew or cargo), RAM's, and RAM support sections. Six shuttle missions are required for delivery of the initial space station modules. A total of 20 shuttle missions is required for the delivery of crew and cargo to the initial station. The shuttle launch frequency for delivery of crew and cargo is dictated primarily by considerations of crew rotation since these missions occur at a frequency which permits the concurrent delivery of the cargo necessary for the support of the station and experiment operations.

Table 3-7. Average Cargo Requirements

Logistics Item	Resupply Requirement (lb/30 days)
Clothing	76
Linens	62
Grooming	10
Medical	15
Utensils	56
Food	650
Gaseous storage	
Oxygen	3
Nitrogen	247
Water	369
Special life support LiOH	10
Water management	40
Atmospheric control	217
CO_2 management	57
Waste management	27
Hygiene	11
Spares	34
Subtotal	1881
Average experiment Resupply	1000
Total 30 Day Average	2884
Up-down emergency (196-hours) O_2	404
H_2	23
Total Emergency	427

The logistics capability for crew and cargo delivery is based on a cargo module capacity of approximately 11,800 pounds per flight for shuttle missions which concurrently deliver up to six crewmen. As previously noted, the cargo requirements are approximately 2900 pounds per month for the initial space station.

In addition to the shuttle missions required for the delivery of the station modules and for crew and cargo delivery, missions are required for the delivery of RAM's and the support sections necessary for the operation of detached RAM's. For the initial station experiment program previously identified, only two support sections are required to support detached RAM operations. This includes one spare. These support sections are periodically returned to earth for refurbishment and redelivered to orbit for further utilization.

Table 3-8. MSP Statistical Summary

		Calendar Year					
		81	82	83	84	85	86
Station Modules	UP	6					
	DN						
Cargo Modules	UP		5	5	3	3	4
	DN		4	5	3	3	4
RAM's	UP		1	1	1	2	1
	DN			2		1	1
Support Sections	SS1						
	SS2						
Crewmen	UP	*	30	30	18	18	24
	DN		24	30	18	18	24
No. Shuttle Flights		6	6	8	4	7	5

Initial Buildup

Initial OPS -6 men

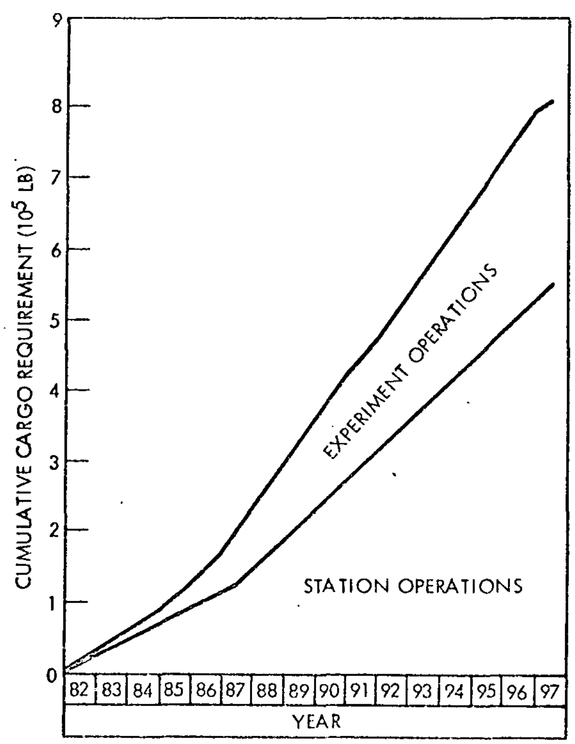


Figure 3-9. Cumulative Cargo Requirements

The resultant total shuttle support requirement is 36 flights for the initial space station. The resultant launch frequency is approximately one every eight weeks for the initial space station.

3.1.1.2.2 Maintenance

There is no routine plan for module replacement for subsystem maintenance.

The normal maintenance of flight hardware shall be accomplished on orbit at the inflight replacement unit level. Scheduled and unscheduled maintenance on-orbit shall not exceed 180 man-hours per month.

The capability for station module deactivation or replacement is provided; however, this is considered an unscheduled major event (i.e., the result of an accident, not a failure).

Critical functions shall be re-allocated to permit mission continuation at a reduced level during module replacement or deactivation.

The maintenance concept for ground systems is to be determined.

3.1.1.3 Personnel and Training

3.1.1.3.1 Personnel Categories

To identify the training required, NASA personnel assigned to the MSS program are grouped into three categories, projected from Apollo experience:

1. Mission Operations - Station crew members who perform as station and experiments management and operator personnel on orbit; mission management personnel who perform mission planning, flight operations, etc.; station tracking personnel; and flight support personnel who supervise design and development of simulators, etc.

2. Support - Design and development personnel who direct and monitor MSS subsystem design activities; test and evaluation personnel; and reliability, quality control, and safety personnel.

3. General - Administrative personnel.

3.1.1.3.2 Training Requirements

The process by which detailed requirements are provided depends on mission and operations functions, the crew interface with these functions, and the man-machine trade decisions made during design definition.

Crew tasks and skills requirements are based on mission and operational functional analyses and on hardware management and operation requirements. The crew tasks are broken down into elements of work, and from these data, the tasks and elements are logically grouped to identify requirements for training, training equipment, graphics, courses, and course material.

3.1.2 PROJECT DEFINITION

3.1.2.1 Project Description

The modular space station project consists of the on-orbit MSS system, the premission operations support system, the mission operations support system, and the cargo module system. Figure 3-10 shows the project specification tree and Figure 3-11 is a functional block diagram of the MSS system.

The on-orbit portion of the project is assembled by the shuttle from modules carried in the orbiter cargo bay. It provides the capability to support a long-duration earth-orbital experiment program.

The ground-based portion of the project builds and tests the flight hardware and provides long-range and logistics support of the mission.

3.1.2.2 Project Elements List

The space station project contains four functional systems which provide the hardware to meet the performance requirements specified in Paragraph 3.3.1 through 3.3.4. These systems are:

1. Modular Space Station System - The modular space station system provides the on-orbit living and working space, including a general-purpose laboratory capability, for six crewmen.

2. Cargo Module System - The cargo module system provides the container to transport and store the space station consumables and emergency supplies. It also supplies a habitable environment for use during shuttle flights involving MSS crew rotation.

3. Premission Operations Support System - The premission operations support system provides the facilities, equipment, and services required to develop, fabricate, and test the new hardware required for the space station project.

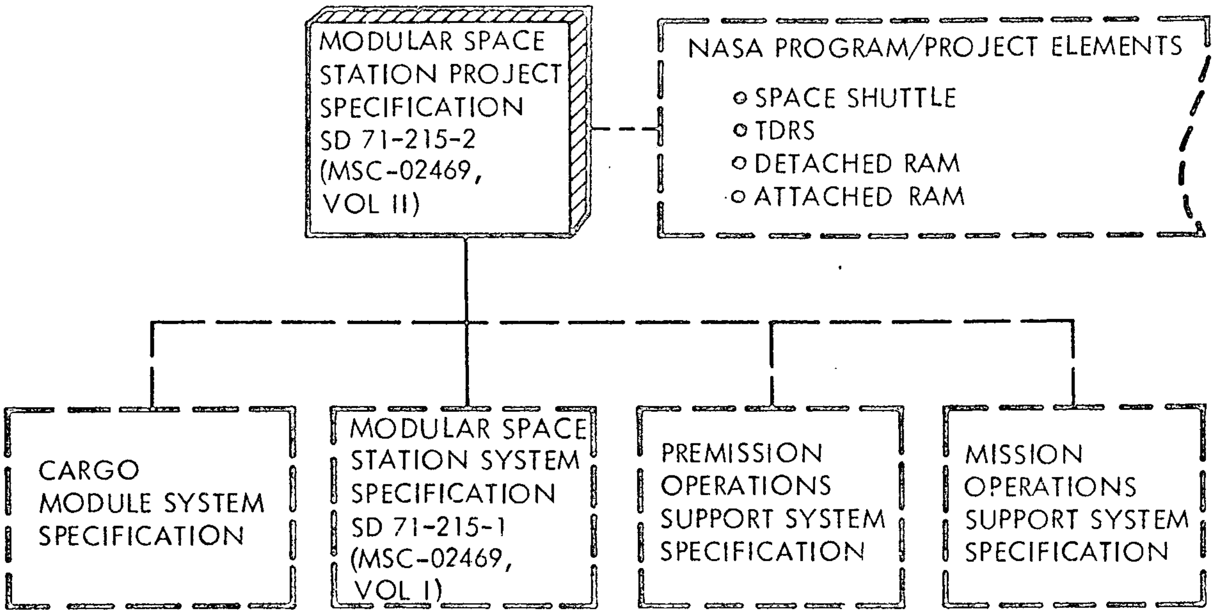


Figure 3-10. Specification Tree

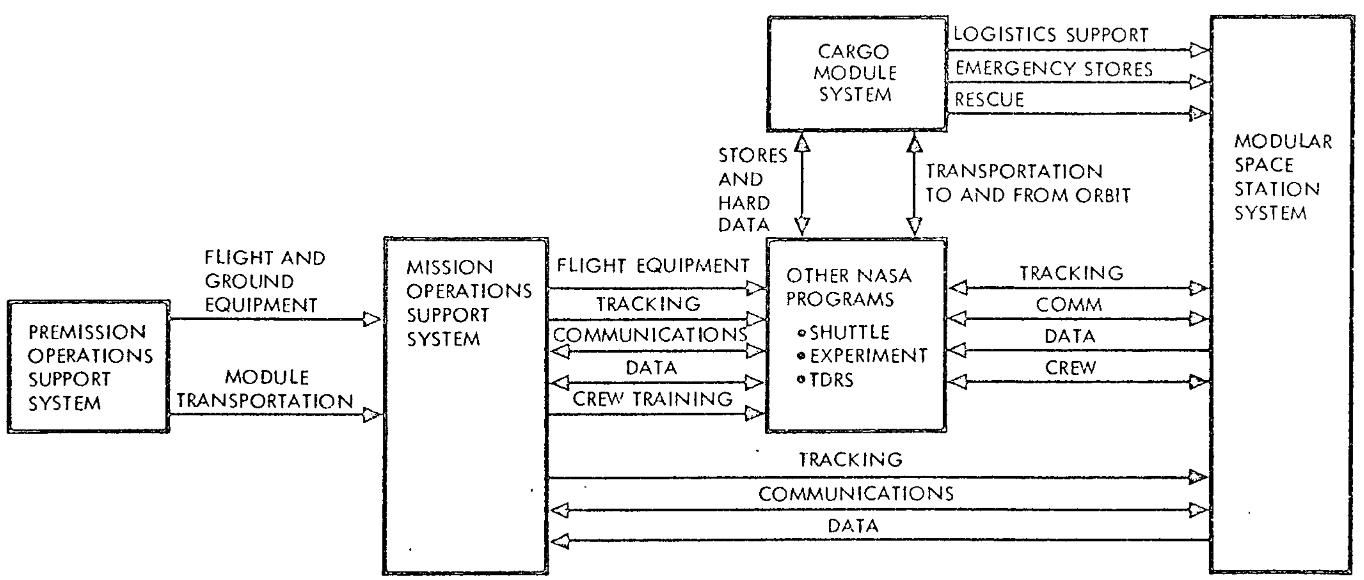


Figure 3-11. Functional Block Diagram

4. Mission Operations Support System - The mission operations support system provides the facilities, equipment, and services required to support the modular space station mission.

3.1.3 OPERABILITY

The operability requirement shall be as specified in system (or lower level) specifications (refer to Volume I, paragraph 3.1.3, for MSS system operability requirements).

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3.2 SYSTEM DESIGN AND CONSTRUCTION STANDARDS

3.2.1 DESIGN COMPATIBILITY

The maximum external dimensions of the modules shall be 14 feet in diameter and up to 58 feet in length. Mechanisms that are external, but attached to the module, such as handling rings, attachments for deployment, berthing mechanisms, storage fittings, thrusters, etc., shall be contained, at launch, within an envelope of 15 feet in diameter and 60 feet in length.

The space station project modules will be launched pressurized.

The space station shall be designed to accommodate additional modules for the growth station which will be assembled in orbit at a later date.

Potentially explosive containers such as high-pressure vessels or volatile gas storage containers shall be placed outside of and as remotely as possible from personnel living and operating quarters, and isolated and protected so that a failure of one will not propagate to others.

The target weight of the modules shall not exceed 20,000 pounds. Target weight includes dry weight, consumables, experiment provisions, and buildup provisions. The module shall be designed to structural loads resulting from a maximum weight of 25,000 pounds.

Each module shall be designed around a common reference. That reference shall be such that the crew and equipment orientation is consistent throughout any singular module. As a goal, all common modules will have the same reference.

The space station shall be designed for ease of manufacture, assembly, inspection, and maintenance. Insofar as practicable, space station component parts shall be interchangeable or replaceable. When practical, modular packaging of hardware, including modifications, shall provide interchangeability.

Vehicle fluid systems and their servicing equipment shall be designed to permit complete flushing and draining during ground checkout.

3.2.2 DESIGN CRITERIA

3.2.2.1 Factors of Safety

Factors of safety for ground equipment will be determined in Phase C/D and shall conform to state and federal regulations. The following factors of safety shall be used for structural design, applied to limit load for flight systems:

Condition	Factor of Safety	
	Ultimate	Yield
Unmanned	1.50	1.20
Manned		
Long-term sustained loads	2.00	1.50
Short-term transient loads	1.75	1.30

All flight pressure vessels shall be designed with an ultimate factor of safety of at least 2.0. Tanks used as gas accumulators in inhabited areas shall be designed to a factor of safety of 4.0 as a minimum.

3.2.2.2 Limit Condition

No system shall be designed incapable of functioning at limit load conditions.

3.2.2.3 Fail Safe

System or component failure shall not propagate sequentially (i.e., design shall fail safe).

3.2.2.5 Design Margins

All space station systems shall be designed to positive margins of safety.

3.2.3 SELECTION OF SPECIFICATIONS AND STANDARDS

All specifications and standards applicable to the premission operations support system launcy-essential or mission-essential equipment as well as all flight equipment shall be selected in the following order of precedence, unless such selection is prohibited by the criticality category of qualification requirements. For premission and mission operational support system equipment which is not launch-essential or mission-essential, intended use, commonality, availability, and cost considerations shall govern the selection of applicable specifications and standards. The order of precedence is:

1. Federal specifications and standards approved for use by NASA
2. Military specifications and standards (MIL, JAN, or MS)
3. Other government specifications and standards (NASA, etc.)
4. Industry specs and standards
5. NR SD specifications and standards

3.2.4 MATERIAL, PARTS, AND PROCESSES

Material, parts, and processes to be incorporated shall be selected with the following considerations:

1. Materials, parts, and processes shall be suitable for the purpose intended. Safety, performance, reliability, long life, and maintainability of the item are of primary importance.

2. Where possible, materials and parts shall be of the kind and quality widely available in supply channels.

3. When practicable, materials, and parts shall be nonproprietary.

4. Whenever possible, single source items shall be avoided.

5. When practicable, equipment shall be designed with a minimum of adjustable components.

3.2.5 STANDARD AND COMMERCIAL PARTS

Intended use, commonality, availability, and cost considerations will govern the selection between government standard and commercial parts.

3.2.6 MOISTURE AND FUNGUS RESISTANCE

Fungus-inert materials shall be used to the greatest extent practicable. Fungus-nutrient materials may be used if properly treated to become fungus-resistant. The treated material shall meet the fungus test in MIL-SID-810. Materials that are not fungus resistant may be used in hermetically sealed equipment and other qualified uses that shall not adversely affect equipment performance or service life.

3.2.7 CORROSION OF METAL PARTS

Design shall use metallic materials chosen for their corrosion-resistant characteristics. All metal parts shall be suitable protected to resist corrosion during normal service life.

3.2.7.1 Electrical Conductivity

Materials used in electronics or electrical connections shall have such characteristics that, during specified environmental conditions, there shall be no adverse effect upon the conductivity of the connections.

3.2.8 INTERCHANGEABILITY AND REPLACEABILITY

Design shall include ease of manufacture, assembly, inspection, and maintenance. Insofar as practicable, component parts shall be interchangeable or replaceable in accordance with MIL-J-8500. When practical, modular packaging of hardware, including modification, shall provide interchangeability.

3.2.9 WORKMANSHIP

All parts and assemblies shall be designed, constructed, and finished in a thoroughly workmanlike manner. Contractual specifications, where applicable, shall be the governing criteria for workmanship. Areas involving workmanship not covered by contractual specifications shall be in accordance with best accepted manufacturing practices and of quality to assure safety and provide operational and service life. Special attention shall be given to neatness and thoroughness of assembly, wiring, marking of parts and assemblies, finishing, fitting, and freedom of parts from burrs, sharp edges, and protuberances.

3.2.10 ELECTROMAGNETIC INTERFERENCE

3.2.10.1 Subsystem Interferences

The design requirements incorporated to assure electromagnetic interference-free operation shall be those specified by MIL-STD-461 for electromagnetic emission and susceptibility, and MIL-B-5087 for electrical bonding. Details of these requirements shall be defined in the MIL-E-6051 required electromagnetic interference control plan.

3.2.10.2 System Compatibility

The design requirements incorporated to assure total end item electromagnetic compatibility shall be those specified by MIL-E-6051.

3.2.11 STORAGE

Storage requirements shall be in accordance with specifications and storage requirements approved by NASA.

3.2.12 DRAWING STANDARDS

The space station drawings associated lists and markings shall be in accordance with the space station configuration management requirements.

3.2.13 COORDINATE SYSTEM STANDARDS

A standard coordinate system shall be established for each MSS system (refer to Volume I, paragraph 3.2.13, for the MSS requirements).

3.2.14 CONTAMINATION

Equipment or material sensitive to contamination shall be handled in a controlled environment. Fluids and materials shall be compatible with the combined environment in which they are employed. Process specifications will be formulated to prescribe handling and application methods.

3.3 SYSTEM REQUIREMENTS

3.3.1 REQUIREMENTS FOR MODULAR SPACE STATION SYSTEM

3.3.1.1 Performance Requirements

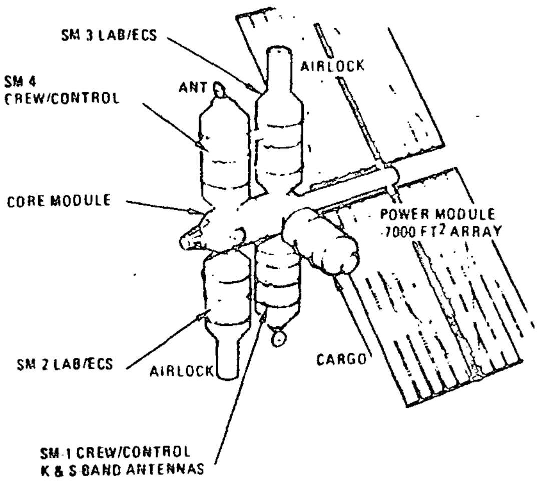
The detailed performance requirements for the MSS system are contained in Volume I of this specification. The overall requirements and characteristics are contained in the following paragraphs. The MSS system consists of a cluster of four common station modules and two special modules (core and power) arranged as shown in Figure 3-13 and with the dimensional characteristics as shown in Figure 3-13. Each module of the system is capable of being transported to and from orbit internal to the space shuttle for on-orbit assembly. The initial station system has the ability to support at least six crewmen, has a general-purpose laboratory capability, and has the ability to accommodate two attached or detached research and applications modules. The GPL capability includes two airlocks, one earth-oriented and the other zenith-oriented. A cargo module also is shown in the figures.

The MSS system is designed and sized for operation at an altitude of 240 nautical miles and an inclination of 55 degrees. The basic flight mode is with the X axis perpendicular to the orbit plane (X-POP), the Z axis along the local vertical (Z-LV), and the Y axis opposite to the velocity vector (Y-OVV). This mode will be flown at all times except for short periods of inertial flight for solar and stellar viewing and shuttle approach and berthing-unberthing operations. The system is capable of operating at altitudes between 240 and 270 nautical miles at an inclination of 55 degrees in either a local vertical hold or inertial hold flight mode.

The end items comprising the modular space station consist of two special modules and four common modules. These are described in the following paragraphs.

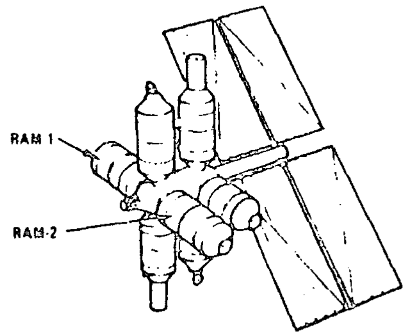
3.3.1.1.1 Core Module

The core module is 40 feet long between berthing interfaces and 12 foot 8 inches in outside diameter (Figure 3-14). The 15-foot-diameter envelope intersects the edges of the side-berthing ports cluster. Lightweight skin (0.040-inch aluminum) and stringer construction is utilized. The eight side-berthing ports are spaced 20 feet apart, which allows a 5-foot clearance between the station modules. The four side parts are provided with thermal covers. Thermal control of the vertical ports is provided during buildup with special insulation panels.



- MODULES
  - FOUR COMMON STATION MODULES
  - TWO SPECIAL MODULES
  - ONE CARGO MODULE
- ASSEMBLY/REPLACEMENT
  - MANIPULATOR BERTHING OR DIRECT DOCKING
  - ON ORBIT REPLACEMENT ANTENNA PACKAGES, EXPERIMENT AIRLOCKS & SOLAR ARRAY

OPERATIONAL CONFIGURATION WITH TWO ATTACHED RAMS



VOLUME ALLOCATION

EXPERIMENT ACTIVITY	7649 FT^3
CREW/SUBSYSTEMS	10,648 FT^3
COMMON USAGE	6363 FT^3

Figure 3-12. Modular Space Station Configuration

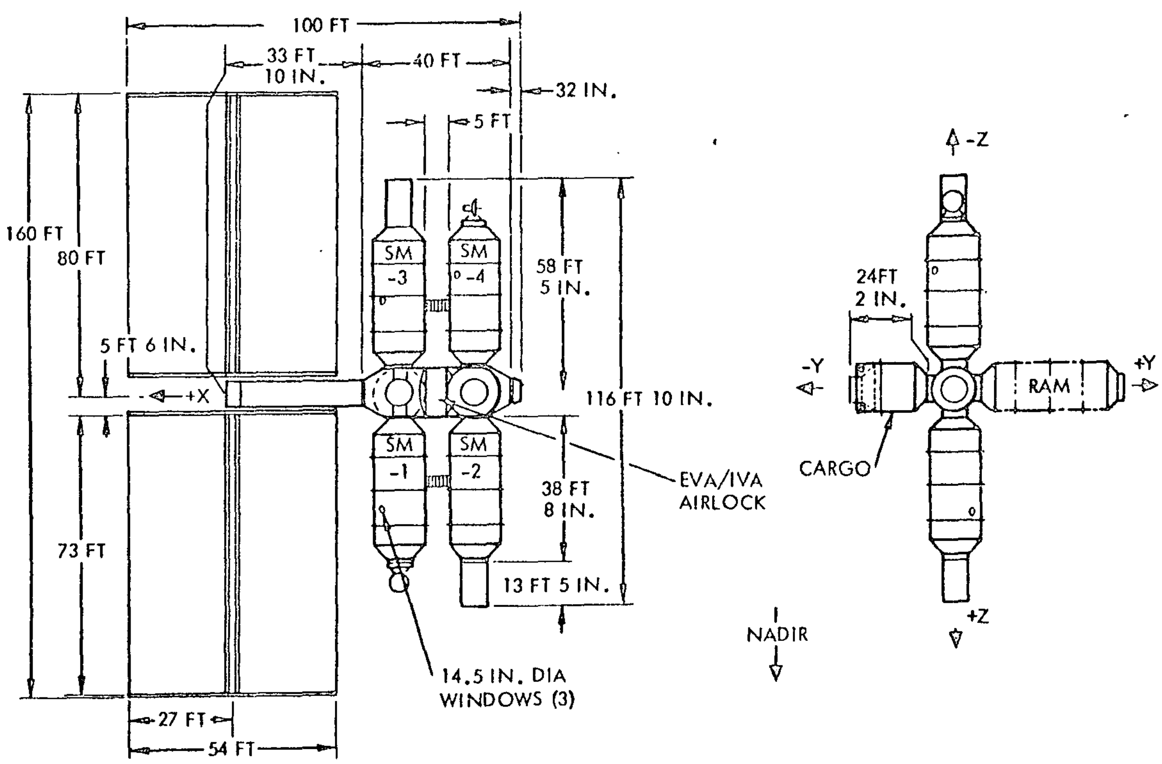


Figure 3-13. Station Dimensional Characteristics

The installed subsystems are distributed between the V1 and V2 volumes separated by the EVA/IVA airlock. The airlock provides an equivalent floor of approximately 5 feet by 7 feet. All of the hatches open outward from the airlock. The EVA hatch (40-inch-diameter clear opening) is located at a 45-degree angle which provides the maximum clearance between attached modules. The guidance and control optical reference and control-moment gyros are located adjacent to the RAM berthing ports.

Certain buildup equipment is accommodated such as the antennas, thermal control radiators, RCS propellant, and initial power reactants and equipment. All subsystem components are installed with on-orbit shirtsleeve maintenance accommodations including maintenance of the RCS engine assemblies. The utilities routing throughout the module from berthing port to berthing port and end to end of the module are redundant and separated for damage containment and safety.

3.3.1.1.2 Power Module

The power module consists of two assemblies, a power boom and a solar array assembly (Figure 3-15). The solar array assembly consists of the arrays and an orientation drive and power transfer mechanism. Shirtsleeve maintenance of the mechanisms is provided. The solar array assembly is replaceable and utilizes the standard berthing port.

The power boom is 88 inches outside diameter by 27 feet, 6 inches long. The 88-inch-diameter boom allows the solar array panels to stow within the 15-foot-diameter shuttle payload envelope. The boom is of monocoque construction utilizing 0.145-inch-thick aluminum which increases its stiffness and consequently increases the natural frequency of the total space station assembly. High-pressure gas storage bottles for repressurization are placed in the boom. Shirtsleeve maintenance and replacement is provided even though the module normally is operated unpressurized.

3.3.1.1.3 Station Module Features

All of the station modules are 38 feet 8 inches long between berthing interfaces and provide a 13-foot, 8-inch clear inside diameter (Figure 3-16). The external frames and attach points extend to 15 feet. An active berthing port is provided at the core module interface and a passive port at the other end. The interface provisions across the berthing ports are identical. Each module contains four manipulator sockets for shuttle deployment and four shuttle bay attach fittings. Radiators cover the exterior of the cylindrical portion of the modules.

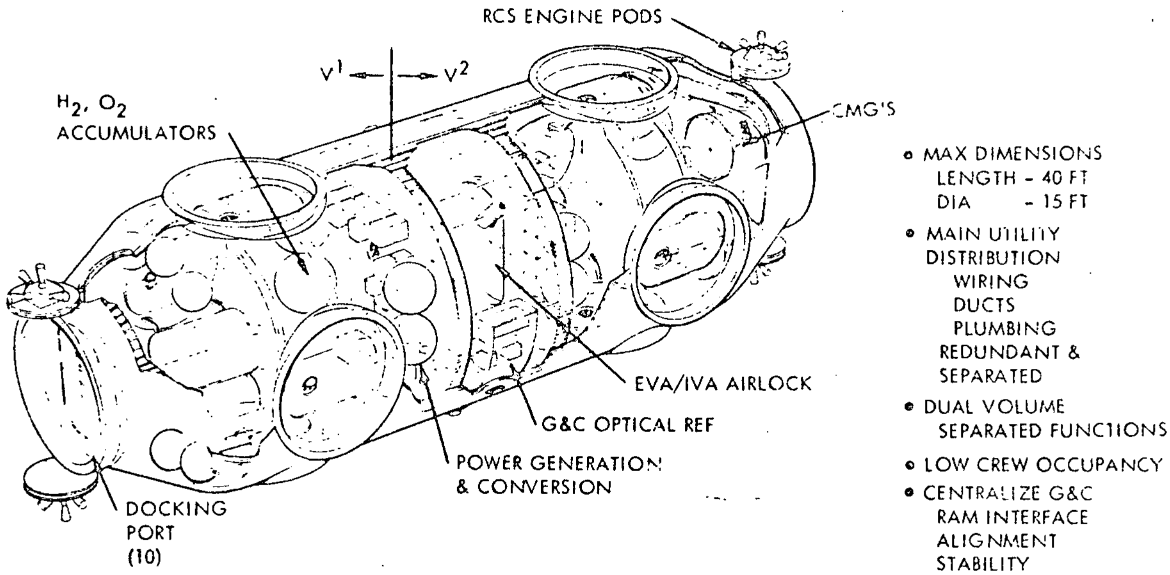


Figure 3-14. Core Module

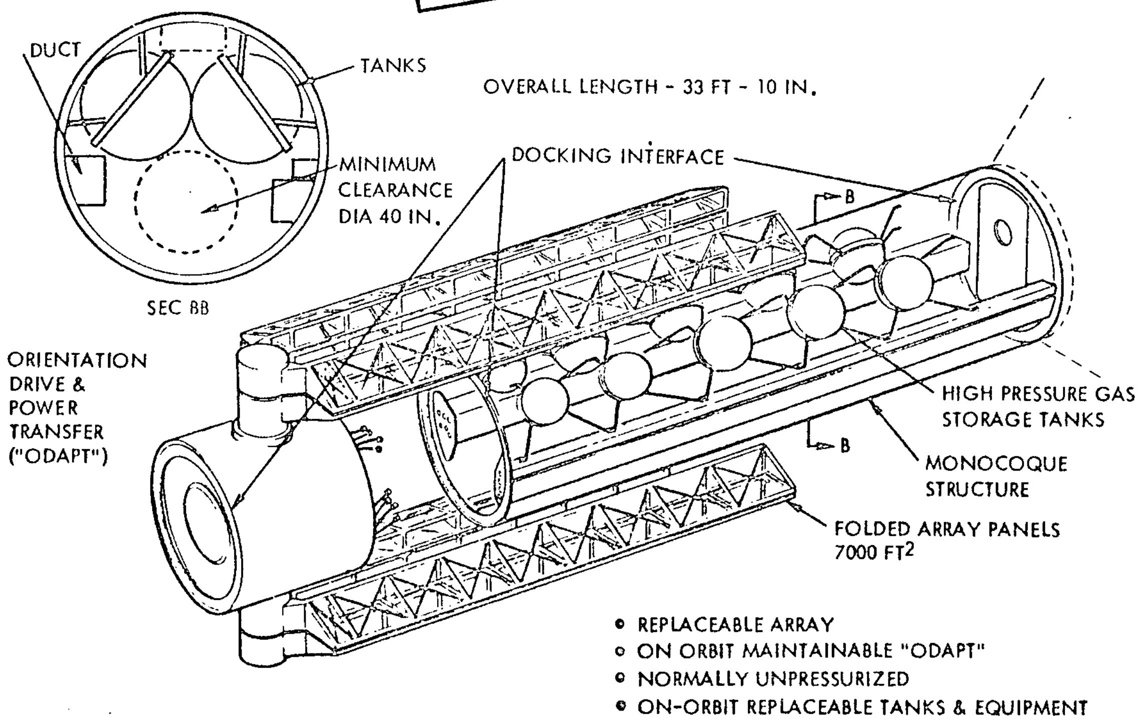


Figure 3-15. Power Module

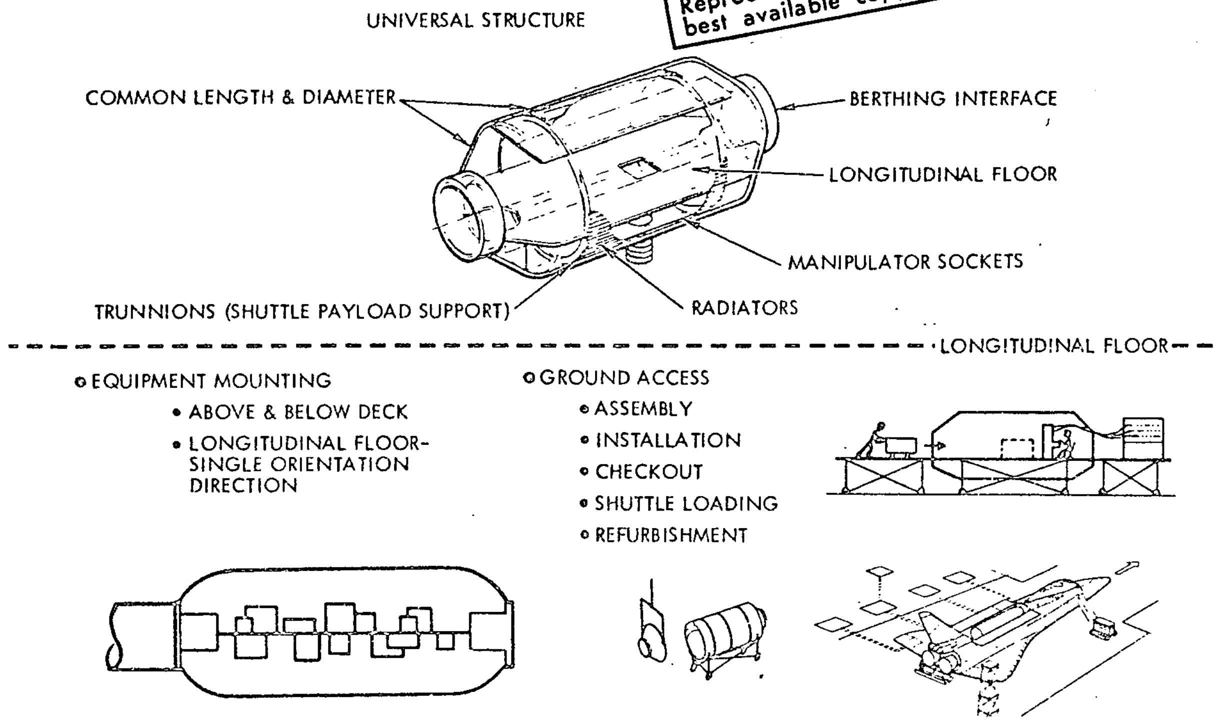


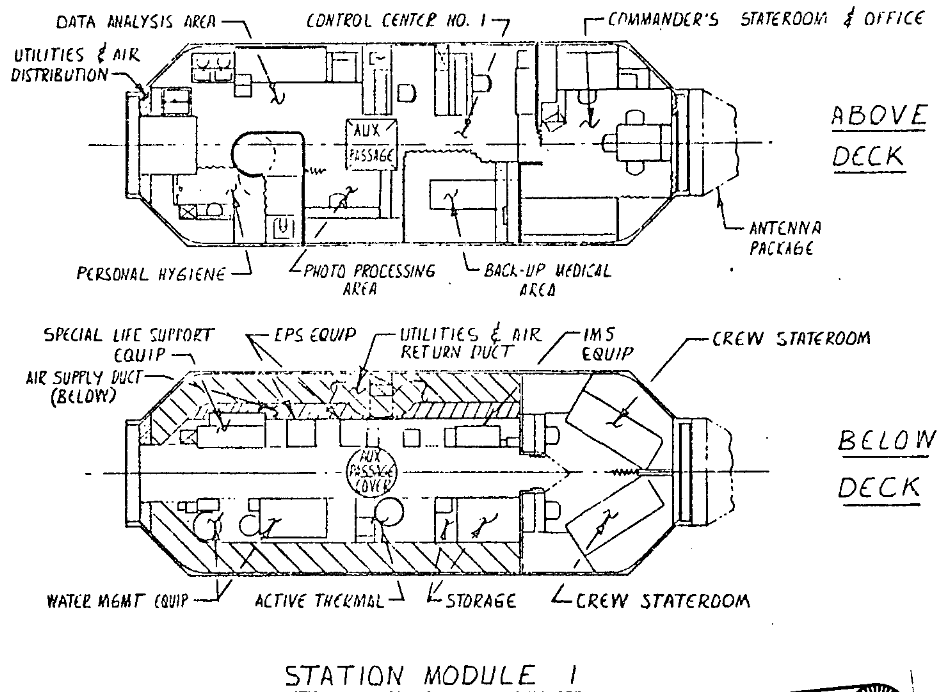
Figure 3-16. Station Module Features

The longitudinal floor provides a single structural component for mounting of equipment both above and below decks, greatly simplifying the manufacturing installation and design details. The longitudinal orientation also simplifies other ground operations of module assembly, checkout, and shuttle installation.

3.3.1.1.4 Crew and Control Station Modules

The two crew and control modules, SM-1 and SM-4, have common functional allocations and equipment location (Figure 3-17). Each module performs a similar function in each of the two pressure-isolatable volumes of the station. Where backup functions are provided, they are located in similar areas in the module of the opposite volume.

Both SM-1 and SM-4 contain a commander/executive-type stateroom and two crew staterooms in a split-level arrangement. Control centers are located on the upper deck of each module outside the stateroom. The personal hygiene facilities are in similar locations; however, only SM-1 contains a shower. The waste management equipment is located below deck near the personal hygiene facility to simplify sewage transport and processing.



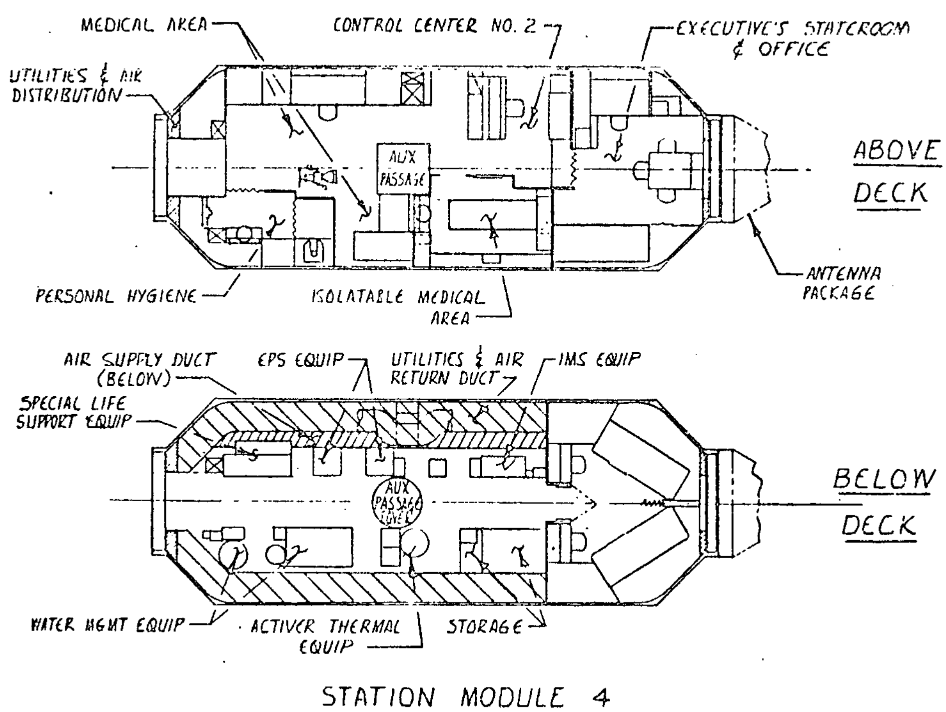


Figure 3-17. Crew and Control Station Modules

The area above deck in SM-1 contains the experiment data analysis equipment, including a data analysis control console, a photo-processing lab, and an isotonic exercise area. The exercise area is also equipped to serve as a backup medical facility. The area above deck in SM-4 contains the primary medical and crew care facilities.

3.3.1.1.5 Laboratory and Environmental Control (ECS)

The two laboratory and ECS modules, SM-2 and SM-3, are in different isolatable volumes of the station (Figure 3-18). Where backup functions are provided, they are located in similar areas in the module of the opposite volume.

The lower deck area of station modules SM-2 and -3 contain environmental control subsystem assemblies for air revitalization (CO_2 management and atmosphere control). Common installation arrangements provide easy access for maintenance and service. The remaining lower deck is for storage of station and experiment supplies.

The above-deck area in SM-3 contain the primary galley/dining and recreation areas as well as general-purpose laboratory facilities. The lab capability is designed to support both physics and biomedical experiments. The above-deck area in SM-2 contains primarily general-purpose laboratory installations; however, a small backup galley is installed at the inboard and of the module. GPL equipment and areas for mechamical, electrical, and optical maintenance are provided.

A general-purpose airlock is attached to these laboratory modules. The one on SM-2 points to nadir, the one on SM-3 to zenith. An experiment operations area and airlock loading access space is provided in each module at the airlock end.

The modular space station system contains seven functional subsystems (Figure 3-19). The detailed requirements and characteristics for each subsystem are contained in Volume I of this specification.

The system power and weight characteristics are summarized in Tables 3-9 and 3-10.

Table 3-9. System Electrical Power Summary

Item	24-Hour Average (watts)
Subsystems	14,667
Cargo Module	100
Experiments	4,500
Total	19,267

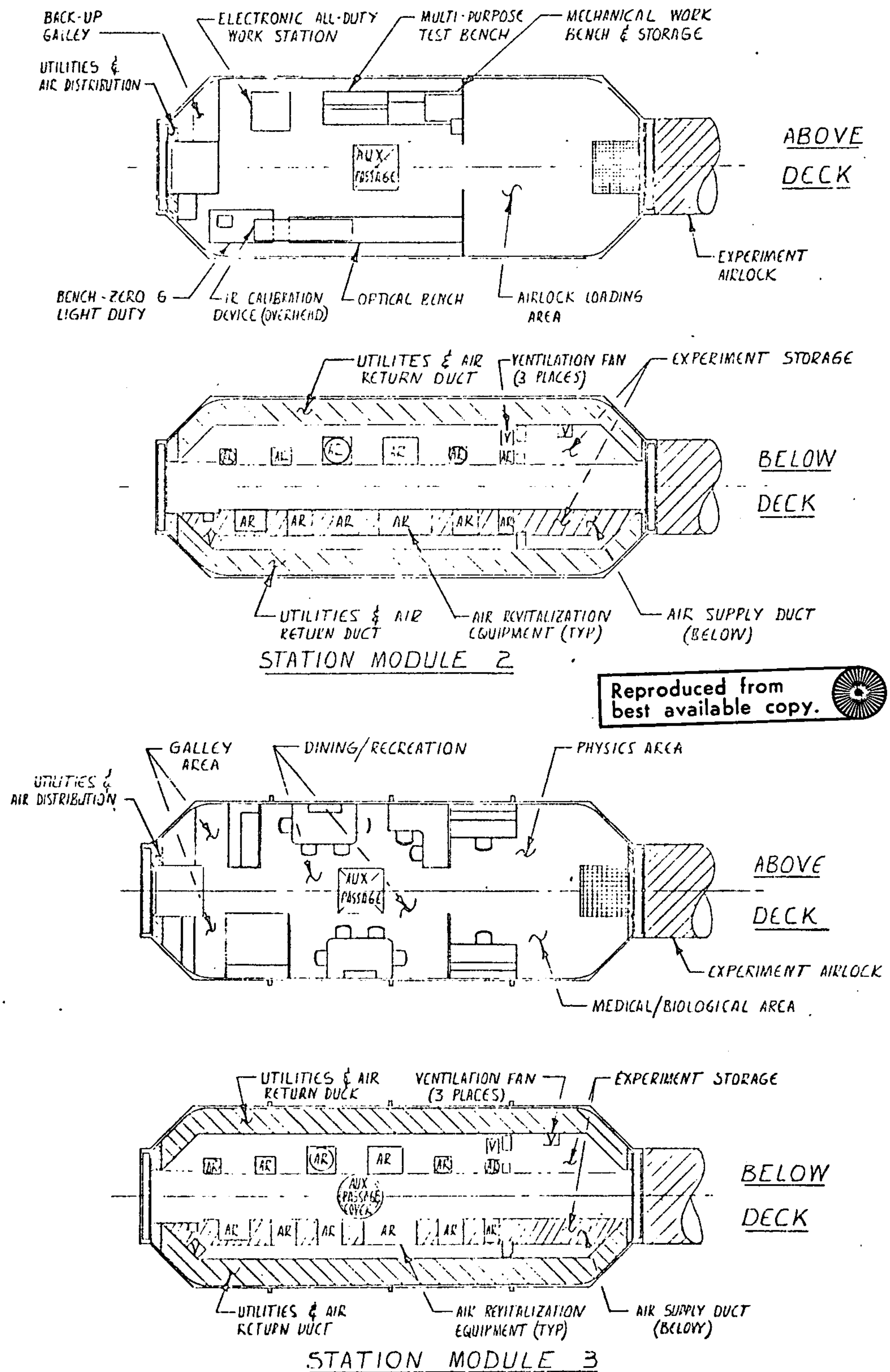


Figure 3-18. Laboratory and ECS Station Modules

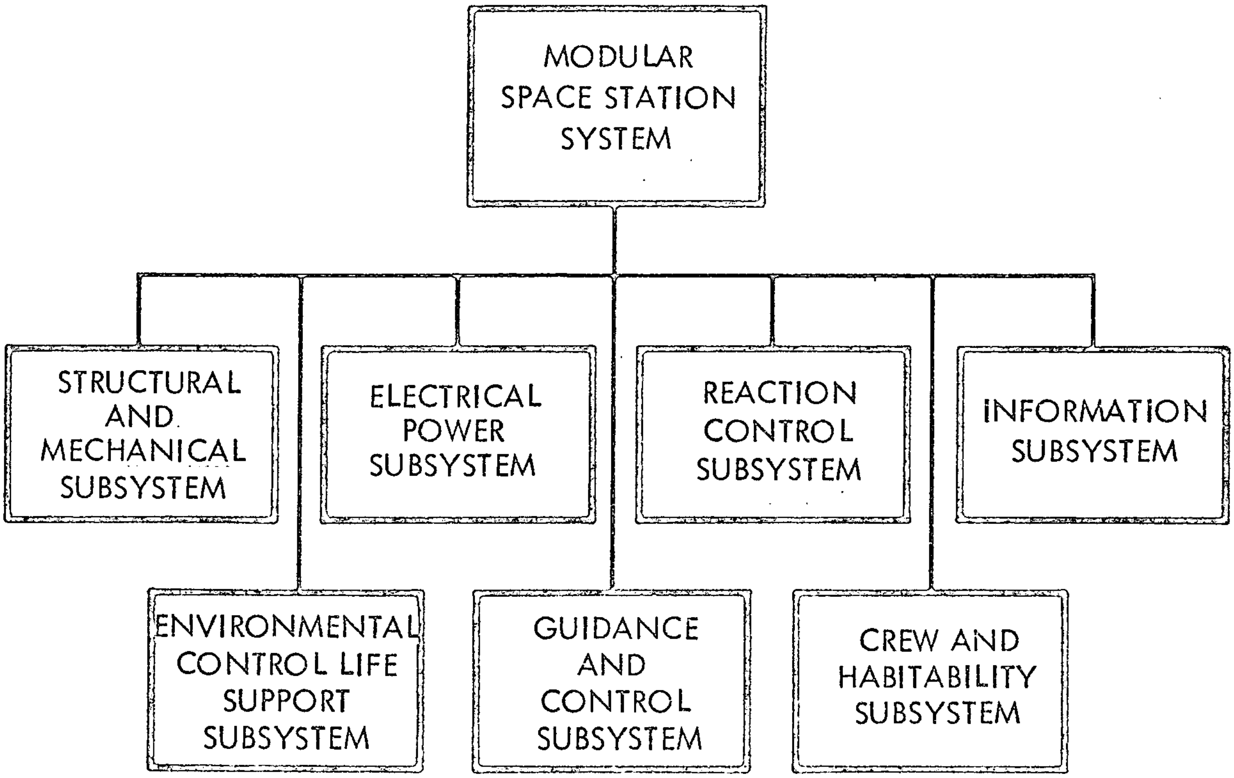


Figure 3-19. Station Subsystems

Table 3-10. Module Dry Weight Summary

	SUBSYSTEM/MAJOR ASSEM	CORE	POWER	SM-1	SM-2	SM 3	SM-4	TOTAL
WBS *	MODULE WBS *	01	02	03	04	05	06	
1	STRUCTURAL & MECHANICAL	12690	3670	10160	12330	10700	9490	59040
1.1	PRIMARY STRUCTURE	5742	1878	4700	4700	4700	4700	26420
1.2	SECONDARY STRUCTURE	3399	410	3218	3350	3446	3378	17201
1.3	ENVIRONMENTAL SHIELD	1119	582	746	735	746	746	4674
1.4	BERTHING	2430	800	490	490	490	490	5190
1.5	GENERAL PURPOSE LAB FURNISH	0	0	1006	3055	1318	176	5555
2	ENVIRONMENTAL CONTROL/LIFE SUPPORT	1619	849	3690	3310	3415	3420	16303
2.1	GASEOUS STORAGE	42	765	0	11	11	0	829
2.2	CO_2 MANAGEMENT	4	0	4	741	741	4	1494
2.3	ATMOSPHERIC CONTROL	750	84	587	876	876	554	3727
2.4	THERMAL CONTROL	681	0	1969	1570	1570	1969	7759
2 5	WATER MANAGEMENT	20	0	638	23	23	638	1342
2.6	WASTE MANAGEMENT	0	0	86	0	79	163	328
2.7	HYGIENE	0	0	370	27	53	56	506
2 8	SPECIAL LIFE SUPPORT	122	0	36	62	62	36	318
3	ELECTRICAL POWER	3790	7800	1762	545	545	1762	16204
3.1	PRIMARY POWER GEN	0	6676	0	0	0	0	6676
3.2	SECONDAY POWER GEN	0	0	0	0	0	0	0
3.3	ENERGY STORAGE	2449	985	766	0	0	766	4966
3.4	POWER CONDITIONING	379	0	16	16	16	16	443
3 5	DISTRIB. CONTROL & WIRING	776	115	834	383	383	834	3325
3.6	LIGHTING	186	24	146	146	146	146	794
4	GUIDANCE & CONTROL	1470	0	0	0	0	0	1470
4.1	INERTIAL REFERENCE	65						65
4.2	OPTICAL REFERENCE	346						346
4.3	RCS ELECTRONICS	75						75
4.4	MOMENTUM EXCHANGE	984						984
4.5	COMPUTATION	0						0
5	REACTION CONTROL	180	0	0	153	153	0	486
5 1	PROPELLANT ACCUMULATOR				88	88		176
5.2	PROP FEED CONTROLS	60			65	65		190
5.3	ENGINES	120						120
6	INFORMATION	462	116	2740	134	161	2640	6253
6.1	DATA PROCESSING	171	91	692	64	64	692	1774
6.2	COMMAND/CONTROL & MONITOR	59	4	478	40	40	478	1099
6.3	EXTERNAL COMMUNICATIONS	193	0	849	0	0	749	1791
6.4	INTERNAL COMMUNICATIONS	39	21	641	30	57	641	1429
6.5	SOFTWARE	0	0	80	0	0	80	160
7	CREW HABITABILITY	733	125	503	233	1271	990	3855
7 1	PERSONAL EQUIPMENT	0	0	0	0	0	0	0
7 2	GENERAL/EMERG EQUIP	733	125	145	145	145	145	1438
7.3	FURNISHINGS	0	0	220	0	160	206	586
7.4	RECREATION/EXER/CREW CARE	0	0	138	0	210	639	987
7 5	FOOD MANAGEMENT	0	0	0	88	756	0	844
SUBTOTAL (DRY WEIGHT)		20944	12560	18855	16705	16245	18302	103611

* WORK BREAKDOWN STRUCTURE CODE

101PDS110597

3.3.1.2 Interface Requirements

3.3.1.2.1 MSS System - Premission Operations Support Systems

The premission operations support system shall provide individual modules in as flight-ready condition as practical through the mission operations support system.

The premission operations support system shall provide the capability to transport individual modules by air.

The premission operations support system shall provide the capability to validate the compatibility and integrated operation of the flight modules to a level consistant with the overall confidence requirements.

The individual modules shall be capable of being transported with their longitudinal and transverse axes in the horizontal plane by air or ground with a limited environmental protection.

3.3.1.2.2 MSS System - Mission Operations Support System

The mission operations support system shall provide the sites, facilities, equipment, and services for the executive direction, management, planning, and operational support of the space station mission.

3.3.1.2.2.1 Mission Management Site

The mission management site provides the management and the long-range planning function for the space station mission.

1. The mission management site shall provide the long-range integrated plans and schedules for launch, resupply, crew rotation, station operation, and experiment operation.

2. The mission management site shall maintain executive control of the mission. It also shall provide the centralized control of communication with the space station mission elements.

3. The overall control of experiment data flow and processing shall be provided by the mission management site. It shall provide the analysis function for assessment of experiment performance based on experiment data provided by the space station through the mission support sites and in the form of down logistics cargo (data tapes, specimens, films, notes, etc.).

4. The space station system shall provide (through the mission support sites) the operational status, experiment program progress, consumables status, and crew status.

3.3.1.2.2.2 Mission Support Sites

The mission support sites shall provide the operational support for flight operations management and experiment operations management in communicating with and acquiring data from flight elements. Mission support sites shall include the TDRS system and ground network, including the switching center.

1. Tracking - The tracking sites shall provide ephemeris data for all flight elements of the space station mission. Tracking accuracy shall be provided to a value to be determined in Phase C/D. The space station shall provide tracking aids to permit ground tracking at space station altitudes up to 275 nautical miles.

2. Communications - Mission support shall provide the acquisition control, display, data processing, and relaying of information from the flight element and provide relaying and transmission of information to the flight elements. During MSS buildup operations mission support shall be capable of generating and transmitting selected RF commands to the MSS.

3. Launch Preparation - Mission support shall provide the capability to: verify the mechanical and electrical interfaces of individual modules, perform selected integrated tests on individual modules, perform selected acceptance tests on individual modules, configure (including loading of bulk and other nonhazardous cargo) for shuttle launch, determine the weight and center of gravity of individual modules, and load and unload individual modules into and from the orbiter cargo bay.

3.3.1.2.2.3 Crew Training Sites

The crew training sites shall provide the indoctrination, familiarization, and procedural practive required for space station crew members:

1. Operations training sites - The operations training sites shall provide training in orbital flight control, subsystem operations, and experiment operations

2. Environmental acclimation sites - The environment acclimation sites shall provide crew training in the environmental effects to be encountered during the space station mission.

3.3.1.2.3 MSS System - Cargo Module System

The cargo module system shall provide the space station related interfaces necessary for the transfer of crew and cargo from the cargo module to the space station and from the space station to the cargo module. The interfaces which are required between the cargo module system and the space station after the cargo module has been berthed to the space station core module are defined in the following paragraphs.

The cargo module system shall provide the storage capability for 1392 pounds per 120 days of environmental control and life support system (ECLSS) resupply water. The capability shall be provided for transfer of the ECLSS resupply water from the cargo module system to the space station system at a pressure of 300 psia.

The cargo module system shall provide storage capability for the types and quantities of gases shown in Table 3-6 to support space station ECLSS operations.

Table 3-11. Cargo Module Gas Storage

Support Function	Gas Type - Quantity (lb.)			Interface Pressure (psia)
	O_2	H_2	N_2	
Emergency ECLSS	222			300
Emergency EPS	160	20		300
Emergency RCS	22	3		300
Leakage makeup			985	300
EVA resupply	128			Greater than 1400

A cargo module repressurization capability and the associated gaseous pressurization lines shall be provided by the space station.

The space station shall provide the capability to equalize the pressure between the space station and the berthing port interface volume following berthing of the cargo module and prior to opening the space station hatch.

The capability shall be provided to equalize the pressure between space station and the cargo module prior to opening the cargo module hatch.

The capability shall be provided to verify the habitability (pressure, temperature and CO_2 partial pressure) of the cargo module prior to opening the cargo module hatch.

The space station system shall provide the cargo module atmospheric control when the cargo module is berthed to the space station. The cargo module is berthed to the space station. The cargo module system interior wall and equipment surface temperatures shall be maintained between 57 and 105 F (especially surfaces exposed to crew contact). The interior temperature shall be maintained at a nominal 70 F when occupied.

The capability shall be provided to circulate the air within the cargo module between 15 and 100 feet per minute.

The cargo module system shall be capable of operating in the environment imposed by the RCSjets located on the space station core module such that exhaust plume impingement on the cargo module system may occur without damage.

The space station system shall provide electrical power for cargo module interior lighting, circulation fans, etc.

The space station-cargo module system shall provide an interface for water coolant lines for thermal control of the cargo module system.

The cargo module system and space station system shall provide devices for transporting cargo between the cargo module and the space station.

The cargo module and space station systems shall provide crew mobility aids in the form of handholds, guide rails, and other devices to facilitate crew locomotion, stabilization, and bracing. The mobility aids shall be capable of use in either a shirtsleeve or suited and pressurized mode of operation.

The cargo module system shall provide crew restraint devices such as tethers, tether attach fittings, harnesses, belts and straps, various foot restraint devices, and articulated or extensible mechanical devices for bracing and stabilization or prevention of inadvertent drift and in a zero-g environment. These devices shall be compatible for use in a suited and pressurized mode of operation.

The cargo module system shall provide radiation dosimeters to measure ambient radiation levels in the cargo module as well as cumulative radiation dosage.

The cargo module system shall provide normal and emergency lighting to support crew activities.

The cargo module system shall provide storage capacity for space station resupply expendables and spares. Types and quantities will be determined in Phase C/D.

The cargo module system shall provide alarms and displays to alert the crew to the presence of a dangerous or potentially dangerous situation. The nature of the displays and the information to be displayed will be determined in Phase C/D.

The cargo module system shall provide two-way intercommunication devices compatible with the space station subsystem intercommunication system. Types and quantities will be determined in Phase C/D.

The space station system shall provide capabilities for monitoring the status of and controlling the cargo module subsystems. The types and quantities of data to be acquired, processed, distributed, analyzed, and stored will be determined in Phase C/D.

The cargo module shall provide the capability to interface with space station closed-circuit TV system.

3.3.2 PREMISSION OPERATIONS SUPPORT SYSTEMS REQUIREMENTS

The premission operations support system shall provide the sites, facilities, equipment, and services required to accomplish the development, manufacture, assembly, checkout, transport, and premission logistics support of MSS modules. For detailed requirements and Phase C/D plans, refer to the MSS Integrated Ground Operations document (SD 71-222, DRL 73).

3.3.2.1 Performance Requirements

3.3.2.1.1 Development Site

3.3.2.1.1.1 Static Environment

Structural tests will be conducted on each unique flight module (core module, station module, power module) to verify structural integrity under static conditions, for each major failure mode. Each module will consist of primary structure only (no secondary structure, no subsystem installations).

3.3.2.1.1.2 Dynamic Environment

Dynamic tests also will be conducted on each unique flight module to verify structural integrity under dynamic conditions and to determine the dynamic energy levels at the subsystem equipment level. In addition, the frequency response characteristics and model shapes of the modules will be determined. To accomplish these objectives, each module will consist of primary structure and all secondary structure required to install floors and dummy equipment. All equipment over 50 pounds will be simulated in terms of mass and c.g. location.

3.3.2.1.1.3 Acoustic Environment

The acoustic environment is anticipated to be sufficiently high to require that transmissibility/attenuation factors be verified prior to subsystem/assembly qualification tests and acceptance tests. To accomplish this objective, the same modules that were used for dynamic testing will also for acoustic tests.

3.3.2.1.1.4 Thermal-Vacuum Environment

Tests conducted in a thermal-vacuum environment are required to resolve some structural and mechanical subsystem development issues. Applying cost-avoidance principles, these issues will be resolved by testing at the assembly and subassembly level as a part of this program.

3.3.2.1.1.5 Integration Testing

Verification of all subsystem functional interfaces, as well as the verification of all space station software, is a vital element of the development effort. To accomplish these objectives, the compatibility assessment vehicle will include a core module, power module, and Station Modules 1, 3, and 4. These modules will have prototype subsystems installed and be fully capable of accomplishing the detailed test objectives with support from GSE and UTE.

3.3.2.1.2 Manufacturing Site

The manufacturing site shall conduct fabrication, assembly, and installation operations in accordance with the manufacturing baseline document, production planning and control directions, and schedule milestones to product quality products at a minimum cost. Manufacturing methods and processes shall be similar to those established on related aerospace programs. Compliance with engineering dimensional tolerances, design, material, process specifications, and other applicable requirements shall be verified by the quality assurance function.

The same manufacturing processes and controls for all deliverable flight hardware and ground support equipment shall be utilized. Each primary element shall be broken down into details, subassemblies, and assemblies to determine the optimum manufacturing sequence, material requirements, and inspection points.

3.3.2.1.2.1 Fabrication

Standard sized parts shall be fabricated using conventional aerospace machine tools and processes. Large detail components shall be fabricated using numerically controlled machine tools, high-capacity press brakes, and stretch-form machines, high-energy forming, and large-scale chemical milling and surface treating processing equipment.

3.3.2.1.2.2 Assembly

Subassembly and assembly of primary structures shall be accomplished by welding, bonding, or mechanical methods. Optimum quality and integrity shall be built into the structure by the use of proven automatic equipment. Certification of qualified personnel shall be required for personnel performing bonding, welding, and critical operations.

The MSS structures shall be assembled in the vertical position for all circumferential welding, where practical, to take advantage of the even gravitational forces, reducing the need for additional tooling and aids for maintaining alignment of the structure as well as the utilization of existing tools and facilities.

Secondary structures and final system installations will be accomplished in the horizontal positions because of the longitudinal floor concepts.

3.3.2.1.2.3 Installation

Secondary structures and subsystems shall be installed using installation methods and techniques developed on other aerospace programs, as determined through manufacturability analysis with engineering. Critical subsystems shall be installed in a clean-room atmosphere as defined by engineering requirements.

3.3.2.1.3 Acceptance Site

Acceptance operations will result in hardware buyoff from vendor to customer or from vendor to vendor. Acceptance of major hardware and software items of the MSS program will include functional and physical configuration audits, which verify that the hardware and software have been satisfactorily developed, and establish that the hardware and software have achieved the specified performance.

Acceptance tests of complete modules will demonstrate performance verification, provide assurance of operational readiness, and provide assurance that all elements of the tested module meet the established requirements.

At the conclusion of acceptance testing, the module under test will be ready for delivery to the next usage point. The acceptance site provides the following:

1. All necessary interfaces with the parts, assemblies, and subsystems.

2. Complete facilities to accomplish checkout, servicing, and mechanical operations.

3. Necessary access platforms, handling, and protective devices.

4. Facilities commensurate with the type of test to be performed and with the test module's environmental requirements.

5. Necessary transportation and protective devices for subsequent delivery.

3.3.2.1.4 Delivery of Test and Flight Modules

Transportation of the flight modules, from the acceptance site to the launch and refurbishment site, will be by means of the Guppy-type aircraft. To accomplish land transportation from the acceptance site to the nearest large commercial or military airfield, highway transporter will be used. Because this device is basically a four-wheeled transporter, it need not be attached to a tractor or truck for nonmoving stability. The wheels can be locked in the nonmoving mode. This design will allow the highway transporter to be loaded directly aboard the Guppy aircraft for tiedown to the aircraft structure.

3.3.2.2 Interface Requirements

3.3.2.2.1 Premission Operations Support System - MSS System

Refer to Paragraph 3.3.2.1.1

3.3.2.2.2 Premission Operations Support System-Mission Operations Support System

The premission operations support system shall provide the capability to deliver individual modules (in as near a launch-ready condition as practical) to the mission operations support system site. In addition, the premission operations support system shall perform individual module acceptance testing for all MSS modules and compatibility testing and integrated testing on the first four modules (core module, power module, SM-1, and SM-2) prior to delivery.

The mission operations support system shall perform receiving inspection on each module received from the premission operations support system.

3.3.2.2.3 Premission Operations Support System-Cargo Module System

The premission operations support system shall be capable of preparing new cargo modules as near ready for launch as practical as the manufacturing site. It shall be capable of cargo module checkout, acceptance testing (module level), and preparation for shipment (with cargo module subsystems deactivated). The premission operations support system also shall be capable of transporting cargo modules to the launch and refurbishment site (part of the mission operations support system) on a module transporter via selected improved roads and special (Guppy-type) aircraft. Cargo modules shall be capable of being transported on module transporters by land or air with limited environmental protection.

3.3.3 REQUIREMENTS FOR MISSION OPERATIONS SUPPORT SYSTEM

3.3.3.1 Performance Requirements

Mission support operations are conducted throughout the MSS Program. During initial program phases actual operational control shall be provided by the mission operations support system. The mission operations support system function shall include mission management, mission support, and crew training. Additional information is provided in the MSS Integrated Ground Operations document (SD 71-222, DRL 73).

3.3.3.1.1 Mission Management

Mission management shall provide the sites, facilities, equipment, and services required to provide the management and the long-range planning function for the MSS system. These required resources (to be determined) will be integrated with similar government and contractor resources required for the shuttle and experiment programs.

3.3.3.1.1 Mission Support

Mission support shall provide the sites, facilities, equipment, and services required to provide tracking and communications with the MSS and to prepare individual modules for launch by the shuttle.

3.3.3.1.1.1 Tracking and Communication

Four present MSFN sites (Goldstone, Madrid, Honeysuckle, and Kennedy Space Center) shall be upgraded for S-band communications with and tracking of the MSS.

3.3.3.1.1.2 Launch Preparation (of MSS Modules)

The facilities, equipment, and services for the following shall be provided:

1. The capability to verify the mechanical and electrical interfaces of individual modules.

2. The capability to perform selected integrated tests on individual modules.

3. The capability to perform selected acceptance testing on new or modified individual modules.

4. The capability to clean (if required) and configure individual modules returned from orbit or received from the manufacturing site (a part of the premission operations support system). This shall include the capability to load bulk and other nonhazardous cargo.

5. The capability to determine the weight and center of gravity of individual modules.

6. The capability to load (and unload) individual modules into (from) the orbiter.

3.3.3.1.1.3 Crew Training

The crew training sites shall provide the indoctrination, familiarization, and procedural practive required for MSS crew members as follows:

1. Operations training sites. The operations training sites shall provide training in orbital flight control, subsystems operations, and experiment operations.

2. Environmental acclimination sites. The environmental acclimination sites shall provide crew training in the environmental affects to be encountered during the MSS mission.

3.3.3.2 <u>Interface Requirements</u>

3.3.3.2.1 Mission Operations Support System-MSS System

Refer to paragraph 3.3.1.1.2.

3.3.3.2.2 Mission Operations Support System-Premission Operations Support System

Refer to paragraph 3.3.2.2.2.

3.3.3.2.3 Mission Operations Support System-Cargo Module System

The mission operations support system shall provide the capability to accept new cargo modules from the manufacturing site and prepare new and returned (from orbit) cargo modules for launch.

Cargo modules returned from orbit shall be capable of being safed while in the orbiter cargo bay at an area adjacent to the orbiter landing strip.

The mission operations support system shall provide the capability to clean and configure cargo modules for crew and cargo or cargo-only flights. The capability to verify the mechanical and electrical interfaces of the cargo modules shall be provided. The capability to perform selected integrated tests (to be determined in Phase C/D) shall be provided.

The capability to load bulk and nonhazardous cargo shall be provided. The capability to determine the weight and locate the center of gravity of cargo modules shall be provided.

The capability to load and unload cargo modules into or from the orbiter cargo bay shall be provided.

3.3.4 REQUIREMENTS FOR CARGO MODULE SYSTEM

The cargo module system shall be the prime carrier of MSS logistics cargo. It shall be launched (or returned to earth) within the orbiter. It shall be capable of supporting six crewmen for 72 hours when on orbit within the cargo bay. It shall be utilized for consumable and supply storage of up to 120 days when berthed to the MSS.

3.3.4.1 Performance Requirements

3.3.4.1.1 Structural and Mechanical Subsystem

The structural and mechanical subsystem shall provide the cargo module pressure enclosure as well as the living and working quarters contained within the structure. It provides for the mounting of associated subsystem hardware and storage. It also provides ports and mechanisms for crew and equipment transfer.

3.3.4.1.1.1 Primary Structure Requirements

The structure shall withstand without excessive defection or failure the induced environments of normal space shuttle flight and the normal landing loads.

The structure shall withstand without excessive deflection or failure the natural environmental conditions.

The primary structure shall be designed in accordance with the factors of safety specified in paragraph 3.2.2.1.

The external dimensions of the modules shall be 14-foot diameter and a maximum length of 58 feet. Mechanisms that are external but attached to the module, such as handling rings, attachments for deployment, storage fittings, and thrusters shall be contained at launch within an envelope 15 feet in diameter and 60 feet in length. Localized external structural framing beyond the 14-foot diameter but within 15-feet in diameter is acceptable.

The primary structure shall be designed for a useful life to be determined in Phase C/D.

The structure shall withstand the forces imposed by manipulator extraction from the space shuttle cargo bay and berthing to the MSS without excessive deflection or failure.

Design of the basic structural element shall be such that all berthing and pressure loads are taken through the primary structure to allow maximum flexibility for internal architectural arrangements. Primary structure is defined as that structure common to all basic structural elements. Floors, partitions, equipment mounting, and other structure peculiar to a particular configuration shall be secondary structure.

As a design goal, the structure of each cargo module shall be designed to limit leakage from the module to 0.5 pounds per day based on a 14.7-psia O_2/N_2 atmosphere.

Cargo modules center of gravity shall be between 180 inches and 648 inches aft of the shuttle-berthing port interface when the module is stowed in the orbiter cargo bay.

Four manipulator sockets located 90 degrees apart circumferentially approximately on the module center of gravity shall be provided.

Module trunnion supports shall be provided to accommodate shuttle payload trunnion retention latch mechanisms.

The structure shall be designed so that any hardware breakup that may occur during a crash landing will be contained within the orbiter cargo bay.

3.3.4.1.1.2 Secondary Structure Requirements

Floors shall be designed to carry the conventional loads of the architectural design and the equipment installed on them. Floors shall be supported to allow for thermal and pressure expansion and contraction. They shall not be a part of the primary structure.

As a goal, equipment and equipment supports shall be arranged or mounted such that the entire inside surface of the pressure shell can be exposed for leak detection and repair.

All equipment installations shall be capable of use for push-off and shall be capable of reacting to crew impact loads (300 pounds limit applied in any direction).

Berthing port hatches shall provide a nominal opening of 5 feet and shall accommodate the passage of crew in pressure suits and package sizes of 40 by 40 by 50 inches.

Window penetration requirements:

1. The MSC 14.75-inch diameter window design shall be utilized.

2. Window penetration design and installation shall provide for shirtsleeve removal and replacement.

3. Placement of windows shall be selected on the basis of minimizing local window optical contamination and adverse environmental conditions (i.e., micrometeoroid penetration).

4. Heat transfer through the windows shall be minimized.

5. Window locations (berthing) - Standard windows shall be provided at each berthing port hatch.

Supports for pressure vessels shall be designed to restrain the vessel under propulsive effects of rapidly escaping gas.

Attachments and bulk cargo containers shall be provided.

3.3.4.1.1.3 Environmental Shield Requirements

Environmental shield shall provide protection for a probability of 0.9 of no micrometeoroid penetration of cargo modules for ten years.

The structure shall provide shielding to limit crew radiation dosage to less than the allowable doses as specified in paragraph 3.1.1.1.1.1.

The thermal control shielding shall limit the heat load gain to the cargo module internal environment from the external environment to a maximum of 1000 Btu per hour.

The thermal control shielding shall limit the heat load loss from the cargo module internal environment to the external environment to a maximum of 2000 Btu per hour.

3.3.4.1.1.4 Berthing Port Requirements

Berthing ports shall be designed to accommodate orbiter manipulator performance characteristics as follows:

Axial velocity = 0.05 fps
Radial velocity = 0.05 fps
Angular velocity = 0.1 deg/sec

Radial alignment = +/- 2 inches
Angular alignment = +/- 1 degree

Berthing ports shall provide utility interfaces within the pressurized volume. The criteria for the utility interfaces is as follows:

1. Hazardous fluid and gas lines shall be barriered and physically separated from power wires and each other (oxygen lines shall be considered hazardous in interface areas).

2. Hydrogen and oxygen lines shall be barriered and separated by a minimum of 45 degrees.

3. Redundant fluid and gas lines shall be separated by a minimum of 45 degrees.

4. As a goal, redundant connectors shall be separated a minimum of 45 degrees (a credible accident to or a credible failure of an interface function or adjacent function shall not cause the loss of the redundantly provided function due to proximity of connectors.)

5. Connectors that contain signal wires shall be separated from connectors that contain power wires by a minimum of 90 degrees.

6. Utility interfaces that are required to establish a shirtsleeve environment within a module must be capable of being mated by a crew member in a pressure suit.

Each cargo module berthing port shall be capable of physically mating with any core module berthing port.

Berthing ports shall be located on both ends of all the modules.

Berthing ports shall be adaptable (field modification acceptable) for direct docking.

3.3.4.1.2 Environmental Control and Life Support Subsystem

The ECLSS shall provide independent on orbit life support capability for six crewman for 72 hours (when required), storage of fluid consumables (oxygen, nitrogen, and water) for up to 120 days, and storage of MSS emergency hydrogen and water high-pressure gases. ECLSS shall have the capability to perform the following functions:

ECLSS shall have capability to store the following quantities of high-pressure gases at launch in addition to 12 pounds of emergency oxygen:

Gas	Quantity (lb.)
Nitrogen	980
Oxygen	290
Hydrogen	15

ECLSS shall have the capability to remove 3 pounds of carbon dioxide per man per day for up to three days.

ECLSS shall maintain an oxygen-nitrogen mixture at a normal operating pressure of 14.7 psia while in the orbiter cargo bay for 72 hours in accordance with the following requirements:

1. Circulation - air velocity shall be maintained between 15 fpm minimum and 100 fpm maximum.

2. Temperature - Air temperature shall be maintained betwen 60 an 80 F.

3. Humidity - To be determined in Phase C/D.

4. Pressure - The atmosphere total pressure shall be maintained at 14.7 psia nominal. Oxygen partial pressure shall be maintained between 3.1 and 3.5 psia maximum.

5. Contaminant control - To be determined in Phase C/D.

ECLSS shall limit the temperature of interior surfaces to a minimum of 57 F and a maximum of 105 F during manned operations and a minimum of 40 F and a maximum of 135 F during manned operations. ECSLL shall prevent the formation of condensation on internal surfaces.

ECLSS shall have the capability to store 2060 pounds of potable water for delivery to the MSS plus 110 pounds of potable water for the crew on crew exchange flights. It shall supply drinking water at 50 F nominally.

ECLSS shall provide fecal and urine collection facilities.

3.3.4.1.3 Electrical Power Subsystem

The EPS shall be capable of storing TBD kilowatt-hours of energy in batteries. It shall be capable of recharging these batteries from the orbiter when in the cargo bay and the MSS when berthed to the MSS. It shall be capable of conditioning and distributing a selected wattage level for 72 hours when manned and a lower level watts when unmanned. The levels will be determined in Phase C/D. It shall be capable of utilizing orbiter power when in the cargo bay and MSS power when berthed to the station. It shall provide the capability to meet the interior illumination criteria.

3.3.4.1.4 Guidance and Control Subsystem

There are no known requirements.

3.3.4.1.5 Reaction Control

Thre are no known requirements.

3.3.4.1.6 Information Subsystem (ISS)

The ISS shall provide the capability to monitor "safety-critical parameters" while in the orbiter cargo bay.

The ISS shall provide the capability to interface with the MSS audio-video bus, the entertainment and paging bus, digital response bus, and digital command bus while berthed on the MSS. ISS shall provide the capability to respond to station ISS digital commands received on the digital command bus. ISS shall acquire, condition, and transmit digital data on the MSS digital data bus on demand. The ISS shall provide a visual and an audible indication upon receipt via the MSS ISS audio-video bus or the entertainment and paging bus.

3.3.4.1.7 Crew and Habitability Subsystem

The crew and habitability subsystem shall provide the capability to reconstitute dried food and dispense drinking water for six crewmen for up to 3 days while in the orbiter cargo bay during crew exchange flights. Six seating restraints and chairs and 25 pounds of food shall also be provided. Mobility aids and restraints, tools, and emergency O_2 masks shall be provided on each flight.

3.3.4.2 Interface Requirements

3.3.4.2.1 Cargo Module System-Mss System

Refer to paragraph 3.3.1.2.3.

3.3.4.2.2 Cargo Module System-Premission Operations Support System

Refer to paragraph 3.3.2.2.3.

3.3.4.2.3 Cargo Module System-Mission Operations Support System

Refer to paragraph 3.3.3.2.3

4. QUALITY ASSURANCE

The quality assurance program defined in the following paragraphs is designed to provide assurance that the space station program elements will achieve mission objectives during their period of projected operational life. Quality assurance begins in the Phase B concept selection process and continues through preliminary design, design, fabrication, assembly, and into the mission operations period. The basic consideration during the Phase B period is to establish the quality assurance issues which require solutions and to fold them into a quality assurance plan which will accommodate the unique aspects of the space station program elements.

A fundamental requirement in accomplishing quality assurance is to establish a plan which will assure delivery of a quality product on completion of the test program. The quality assurance detailed requirements, management approach, and program plan description for Phase C/D are contained in the MSS Program Master Plan (SD 71-225, DRL 76).

Quality assurance is provided throughout the test program as shown in Figure 4-1 by utilizing the data base performance data throughout development test, design proof test, qualification test, acceptance test, prelaunch test, and mission operations. By access to the data base, each detail operation will be assured of analysis, evaluation, and implementation of quality assurance. In addition to utilizing the test data base, quality assurance will be in all phases of manufacturing and installation.

The space station program shall have a quality assurance program in consonance with NHB 5300.4 (1B) to verify that the equipment is capable of performing the space station mission. Each component of every program element will be analyzed for qualification requirements and qualification established from a qualification matrix.

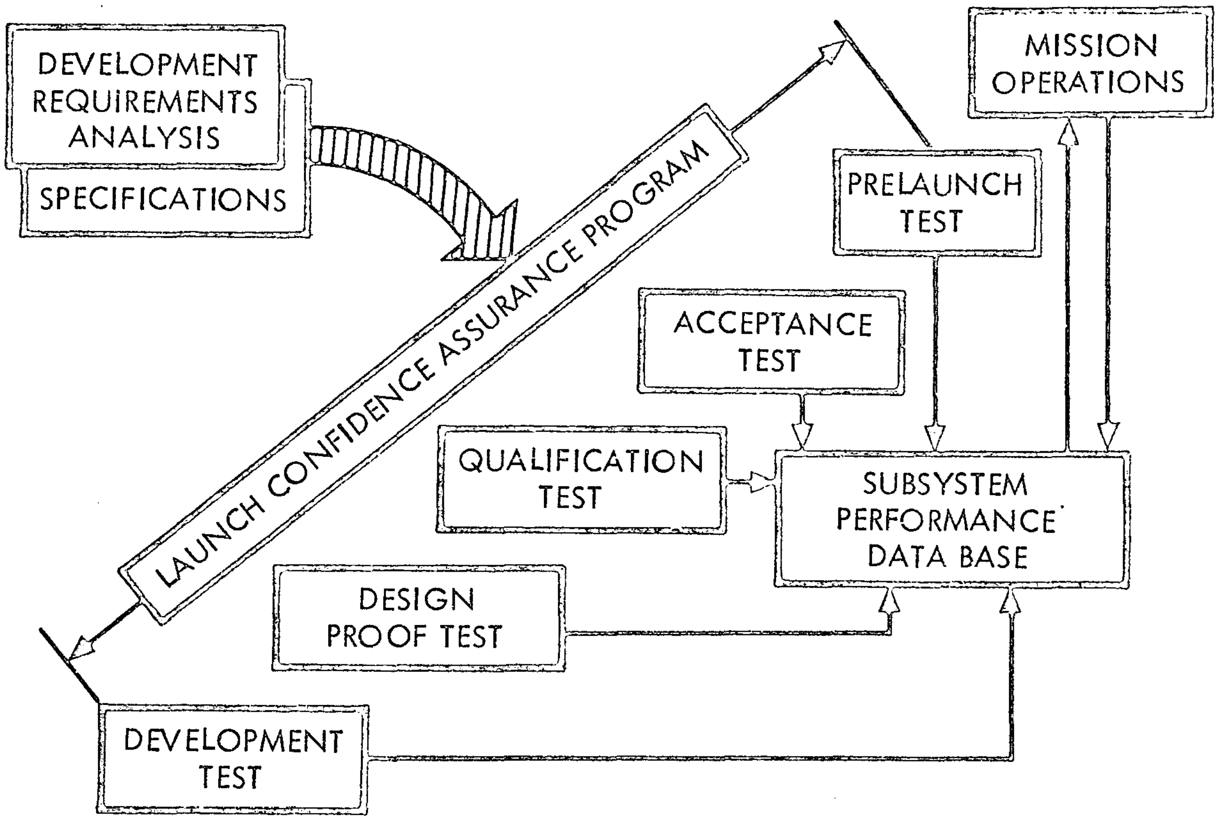


Figure 4-1. Integrated Program

5. PREPARATION AND DELIVERY

The preparation and delivery requirements shall be as specified in systems (or lower) level specifications. For the MSS system requirements refer to Volume 1, paragraph 5.0 of this specification.